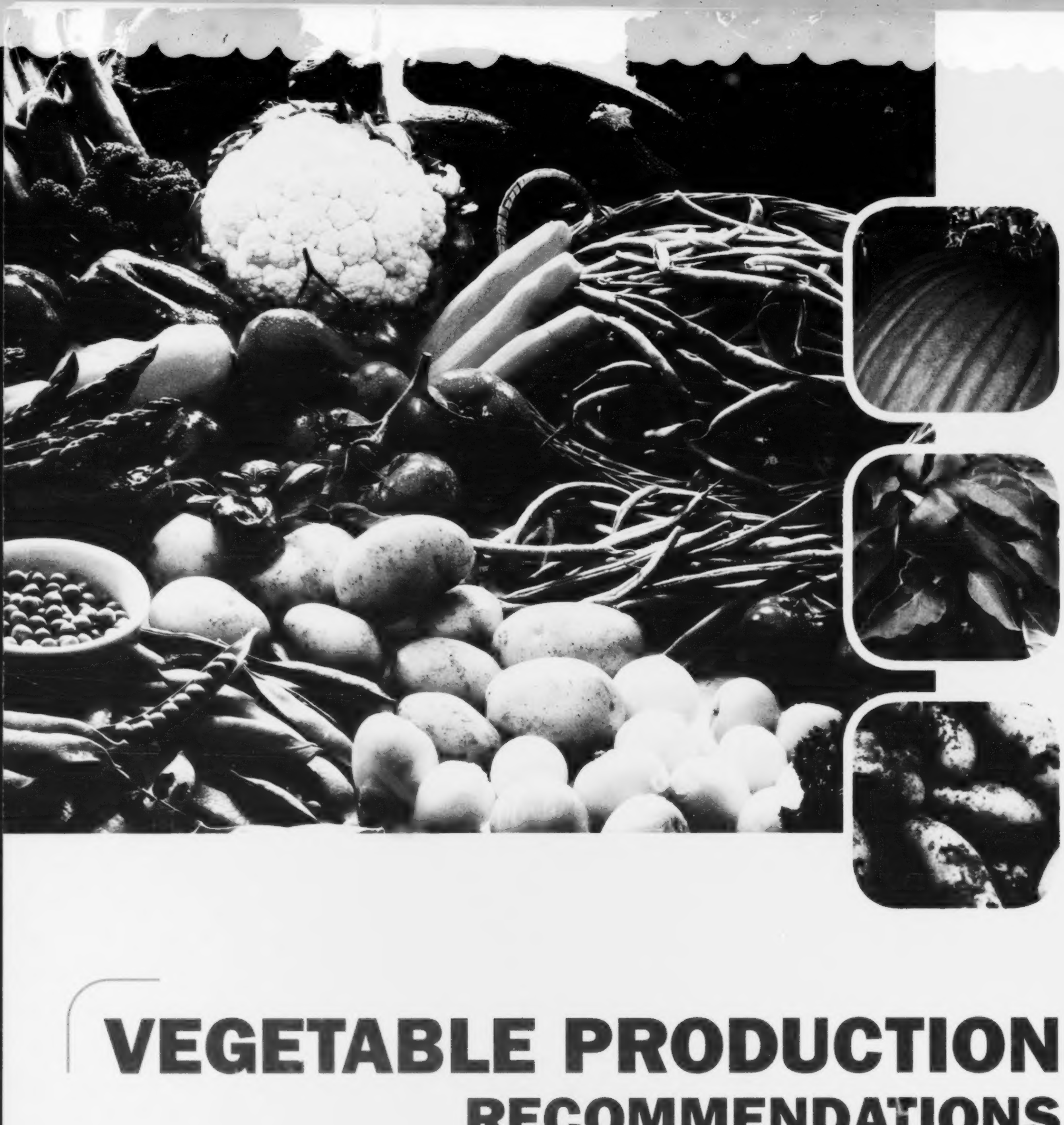

VEGETABLE PRODUCTION
RECOMMENDATIONS
2008-2009

Publication 363

Ministry of Agriculture,
Food and Rural Affairs

Ontario

Discard old editions of this publication. Each year the appropriate sub-committee of the Ontario Pest Management Research and Services Committee reviews the pesticides listed in this publication. To the best knowledge of the committee, at the time of printing, the pesticide products listed in this publication were:

- federally registered
- classified by the Ministry of the Environment.

The information in this publication is general information only. The Ministry of Agriculture, Food and Rural Affairs does not offer any warranty or guarantee, nor does it assume any liability for any crop loss, animal loss, health, safety or environmental hazard caused by the use of a pesticide mentioned in this publication.

This publication lists a number of brand names of pesticides. It is neither an endorsement of the product nor a suggestion that similar products are ineffective.

The Pesticide Label

Consult each product label before you use a pesticide. The label provides specific information on how to use the product safely, hazards, restrictions on use, compatibility with other products, the effect of environmental conditions, etc.

The pesticide product label is a legal document. It is against the law to use the product in any other way.

Federal Registration of Pesticide Products

The Pest Management Regulatory Agency (PMRA) of Health Canada registers pesticide products for use in Canada based on following an evaluation of scientific data to ensure that the product has merit and value; and the human health and environmental risks associated with its proposed use are acceptable.

1. **Full Registration**
Pesticide registrations are normally granted for a period of five years, subject to renewal.

2. **Temporary Registration**
Temporary registration may be granted for a period not to exceed one year, where the registrant agrees to produce additional scientific or technical information, or the pesticide is used for emergency control of a serious pest outbreak.

Maximum Residue Limits

Health Canada has established maximum residue limits (MRLs) for pesticides. Processors or retailers may demand more restrictive limits. Growers should seek advice of their intended market to determine if more restrictive limitations apply. Keep accurate and up-to-date records on pesticide use in each crop.

Supplemental Labels

You MUST obtain a supplemental label and follow all the label directions when PMRA approves new uses for a registered pesticide that do not appear on the current label.

Examples of when you must use a supplemental label include:

- **Temporary Registrations for Emergency Use**
- **Minor Use Label Expansion**

You can obtain a copy of a supplemental label from the pesticide manufacturer or pesticide vendor, the grower association that sponsored the emergency registration or minor use, from OMAFRA or PMRA's Pest Management Information Service.

For more information on the federal registration status check the PMRA website at *www.hc-sc.gc.ca/pmra-arla* or call 1-800-267-6315.

Regulation of Pesticides in Ontario

The Ministry of the Environment is responsible for regulating pesticide sale, use, transportation, storage and disposal in Ontario. Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use, under the *Pesticides Act* and Regulation 914.

All Pesticides must be used in accordance with requirements under the *Pesticides Act* and Regulation 914. The act and Regulation are available on the e-laws website at *www.e-laws.gov.on.ca* or call Publications Ontario Toll-Free number: 1-800-668-9938 or 416-326-5300.

Classification of Pesticides

The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to the Ministry of the Environment, the placement of pesticide products into one of six schedules used to control sale and use. Once approved by the Ministry of the Environment, classified products are posted on the OPAC website: *www.opac.gov.on.ca*. For more information call OPAC at 416-314-9230.

Certification and Licensing

Growers and their Assistants

For information about certification for growers and training for assistants check the Ontario Pesticide Education Program website: *www.ridgetownc.uoguelph.ca/opep/* or call 1-800-652-8573.

Commercial Applicators and their Assistants

For more information about exterminator certification and licensing and technician training check the Ontario Pesticide Training & Certification website at *www.ridgetownc.uoguelph.ca/optc* or call 1-888-620-9999.

Cette publication est aussi disponible en français.

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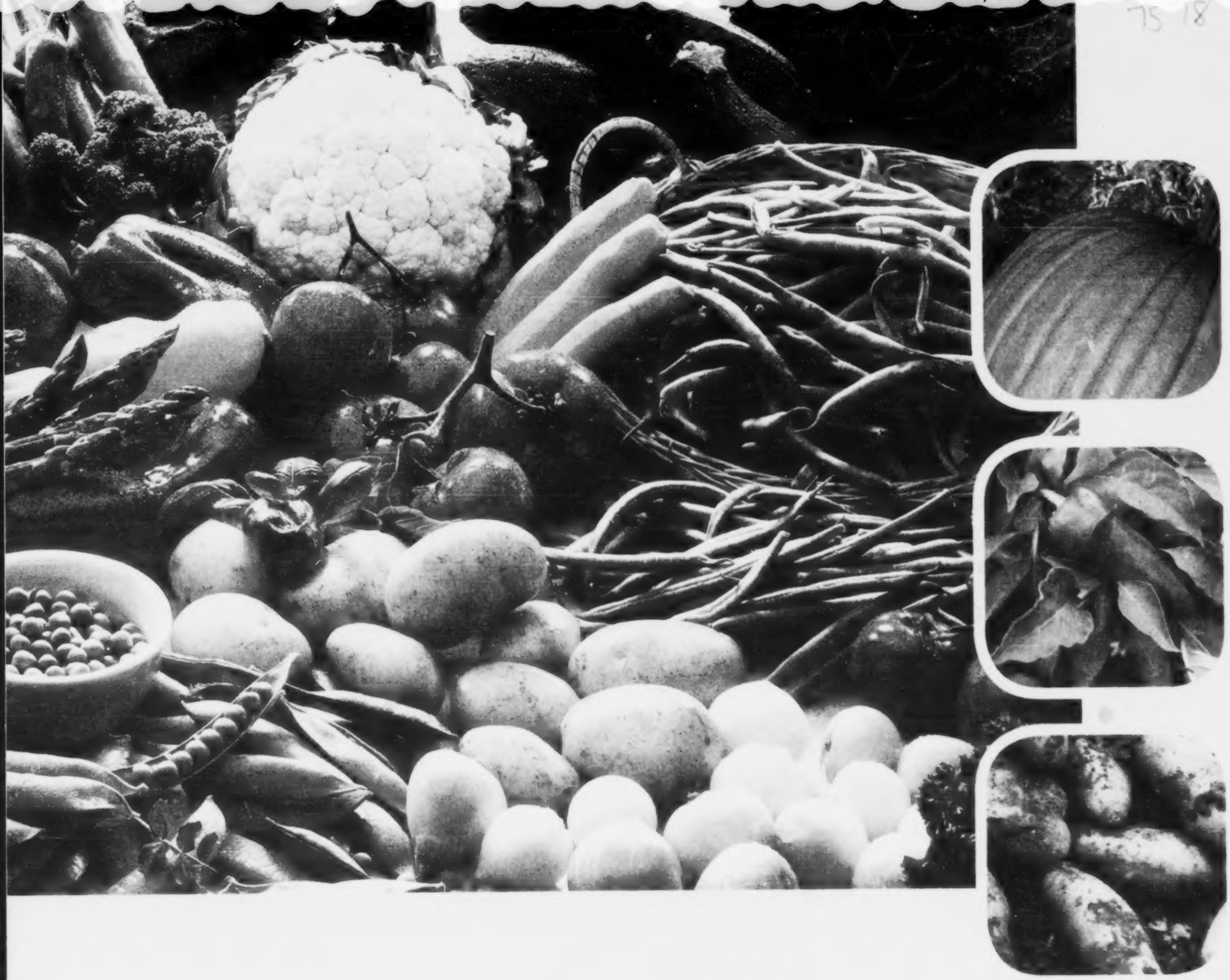

VEGETABLE PRODUCTION
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Ministry of Agriculture,
Food and Rural Affairs

Ontario

Need technical or business information?

Contact the Agricultural Information Contact Centre at:

1-877-424-1300 or ag.info.omafra@ontario.ca

Looking for vegetable production recommendations on the Internet?

www.ontario.ca/crops

It's one-stop shopping for Factsheets, articles and photos
regarding the production and management of Ontario's vegetable crops.

Acknowledgements

The recommendations in this publication have been prepared in consultation with:

- Ontario Pest Management Research & Services Committee
- Ontario Horticultural Research & Services Committee
- Ontario Soil Management Research & Services Committee
- Ontario Weed Committee

and personnel of:

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- University of Guelph
- University of Guelph — Ridgetown Campus
- Ontario Ministry of Environment
- Ontario Ministry of Energy
- Agriculture and Agri-Food Canada

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1. Vegetable Crop Fertility

For a complete guide to soil fertility, see OMAFRA Publication 611, *Soil Fertility Handbook.*

Soil fertility is an important component in the production of high yielding, top-quality vegetable crops. However, soil fertility is only one part of a crop management program. The effectiveness of a soil fertility program will depend on careful soil and water management, as well as crop protection. Developing a good, sound soil fertility program begins with assessing the crop and the soil's nutrient needs.

Assessing Nutrient Needs

There are three ways to assess soil and crop fertility:

- visual deficiency symptoms
- soil testing
- plant analysis

Visual Deficiency Symptoms

Leaf symptoms are helpful for evaluating some nutrient deficiencies. Unfortunately, by the time deficiency symptoms are visible, yield losses may have already occurred. Visual deficiency symptoms may also be easily confused with other production problems, such as herbicide injury, leaf and root diseases, nematodes, insect damage, compaction or air pollution. Suspected visual deficiencies can often be confirmed with leaf or plant analysis. Visual leaf deficiency symptoms are described in the individual nutrient sections in Chapter 9, *Crop Management Recommendations*, starting on page 67.

Soil Testing

Soil testing in Ontario is done by commercial soil-testing laboratories, using tests accredited by OMAFRA (see Table 1–1, *OMAFRA-Accredited Soil Tests*, right). OMAFRA-accredited soil tests are not available for boron, copper, iron or molybdenum. Plant analysis is generally a better indicator of deficiencies of these nutrients. For a list of accredited soil-testing laboratories in Ontario, see Appendix C, *Accredited Soil-Testing Laboratories in Ontario*, on page 228.

Table 1–1.
OMAFRA-Accredited Soil Tests

See Appendix C, *Accredited Soil-Testing Laboratories in Ontario*, on page 228, for a list of accredited labs in Ontario.

Materials	What Is Analyzed[1]
Soils for field-grown crops, commercial turf, etc.	plant-available phosphorus, potassium, magnesium, zinc and manganese pH lime requirement
Greenhouse media	plant-available nitrogen, phosphorus, potassium, calcium, magnesium pH total salts
Nutrient solutions, water	plant-available nitrogen, phosphorus, potassium, calcium, magnesium pH total salts sulphates chlorides

[1] Soil organic matter tests can be useful for herbicide recommendations or for evaluating soil quality but are not accredited tests.

When to Sample

Sample each field once every 2 or 3 years. Potash levels can change quickly on sandy soils where large amounts of nutrients are removed by the crop, especially if there is limited crop residue left on the soil. Examples of heavy potash feeders include alfalfa hay, corn silage, potatoes, sugarbeets and tomatoes. In these cropping systems, consider sampling more frequently.

Sample soils in the fall or in the summer. Make it a habit to sample at the same time each year for more consistent sample results. The period following wheat harvest is often a convenient time in the crop rotation to take samples. Late-summer or fall sampling is ideal for fields to be seeded in the spring. Regardless of when you sample, allow time for mailing the samples and receiving your report.

Taking a Soil Sample

A soil-test report's accuracy and the resulting recommendations depend on properly taking, preparing and submitting a soil sample. To start soil sampling you'll need:

- a soil probe or a shovel
- a clean plastic pail. Avoid using galvanized metal pails; these will contaminate the sample for micronutrient analysis, particularly zinc.

- sample bags and boxes, usually available from the soil laboratory
- a pen or marker

Sample each field separately. Separate large fields and fields with considerable variation into smaller sections. Each field section should have relatively the same soil texture, topograghy, organic matter and cropping history.

Micronutrient deficiencies frequently occur in small patches in fields. In these cases, analysis of soil or plants taken from the entire field is unlikely to find the problem. Sample problem areas separately. When sampling a problem area, be sure to take a comparison sample from an adjacent good area.

For a basic test, sample soil cores to a depth of 15 cm (6 in.). Nitrate-nitrogen samples are taken to a depth of 30 cm (12 in.). Take at least 20 soil cores for fields up to 5 ha (12 acres) in size. Take proportionately more cores for fields larger than 5 ha (12 acres). The more cores you sample, the more reliable the measure of the fertility in the field. One sample should not represent more than 10 ha (25 acres). For more information on nitrate-nitrogen samples, see the section *Pre Side-Dress Nitrogen Test*, on page 7.

Travel the area sampled in a zigzag pattern to provide a good variety of sampling sites. Avoid sampling recent fertilizer bands, dead furrows, areas adjacent to gravel roads or areas where lime, manure, compost or crop residues have been piled.

Break the lumps. Mix the soil well before sending a soil sample for testing. Approximately 2 mL of each sample are used for the analysis so a well-mixed sample will provide greater accuracy. Fill a clean plastic bag with approximately 500 g of soil and place it into the box. Be sure to clearly mark the sample with all the necessary information (i.e., sample number, farm name, date, etc.).

Interpreting the Results

The OMAFRA-accredited soil-testing program provides recommendations for nitrogen, phosphate, potash, magnesium, zinc and manganese fertilizer. It also gives recommendations for the amount and type of lime to be applied, if required. OMAFRA-recommended fertilizer rates are provided in the commodity sections of this publication, starting on page 67 and in Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15, and Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13. These recommendations can produce the highest economic yields when accompanied by good or above-average crop production management.

**Table 1–2.
Soil Test Nutrient Ratings**

Response Category	Probability of Profitable Response to Applied Nutrients
High Response (HR)	high (most of the cases)
Medium Response (MR)	medium (about half the cases)
Low Response (LR)	low (few of the cases)
Rare Response (RR)	rare (very few of the cases)
No or Negative Response (NR)	not profitable to apply nutrients

In a basic soil test, each element is given a numerical value (usually recorded in ppm), a letter rating and a fertilizer recommendation for the crop specified on the soil test submission form (usually in lb/acre). The Ontario soil test nutrient ratings were revised, effective January 1, 2008, to reflect the likelihood of having a large enough response to applied fertilizer, in the year of application, to pay for the fertilizer and allow additional profit for the grower. The rating system is explained in Table 1–2, *Soil Test Nutrient Ratings*, above. Soil tests taken prior to 2008 will still reflect the old rating system. When using an older soil test, select a fertilizer rate based on the numerical (ppm or mg/L) soil test value reported on the soil test.

A soil test recommendation is affected by manure application, plowing down of legume sod and the type of crop to be fertilized. This information is essential for a reliable fertilizer recommendation. Recommended fertilizer rates, especially for nitrogen and phosphorus should be adjusted if manure and cover crops are used.

There are several methods used in developing fertilizer recommendations from soil test results.

OMAFRA-Accredited Recommendations

The OMAFRA-accredited program uses field trials to determine the maximum economic rate of each nutrient. This amount is most likely to maximize profit in the current year. Applying nutrients at the OMAFRA-recommended rate will maintain or gradually increase soil fertility. As a nutrient's soil test value increases, the economic return per unit of fertilizer decreases. The soil test ratings of low response (LR), rare response (RR) or no response (NR) indicate that an economic response to adding more of that nutrient is unlikely. For some vegetable crops, a specific nutrient may be recommended to enhance crop quality. Adding nutrients

Soil Tests From Other Laboratories

Each year, a number of farmers ask how to interpret results from laboratories that are not accredited. Provided the other laboratory uses the identical test used by the OMAFRA-accredited service and expresses its results in the same units, the OMAFRA fertilizer requirements for phosphate and potash can be determined. However, there is no assurance of the accuracy of the analysis.

Only OMAFRA-accredited soil tests can be relied on to provide accurate fertilizer recommendations. Be certain that the service you are using is accredited. To be accredited, a laboratory must use OMAFRA-approved testing procedures, must demonstrate acceptable analytical precision and accuracy and must provide the OMAFRA fertilizer recommendations. Soil tests on farms that must complete a nutrient management plan must be carried out at OMAFRA-accredited labs.

to soils with an NR rating may reduce crop yields or quality by interfering with the uptake of other nutrients.

Crop Removal Recommendations

The crop removal system selects fertilizer rates to replace the nutrients removed in the harvested crop portion. This system does not account for naturally occuring levels of nutrients supplied by the soil. As a result, the rates recommended for phosphorus and potassium are often uneconomical. On soils with a rating of low response (LR), rare response (RR) or no response (NR), the increase in yield may not pay for the additional fertilizer recommended through crop removal calculations. On soils with a high response rating, crop removal may result in an insufficient fertilizer application. Crop removal of phosphorus and potassium is not closely related to phosphorus and potassium fertilizer requirements.

Build-up and Maintenance Recommendations

Build-up and maintenance recommendations aim to meet the crop's annual nutrient requirement and to improve the soil-test value. For soils testing in the low response (LR) range or higher, additional fertilizer is recommended to maintain high soil test levels despite the low probability of an economical response. High levels of some nutrients may interfere with the uptake of others and cause yield reductions. There is no economic advantage to maintaining soil test levels in the rare response (RR) or no response (NR) range. Most crops can be grown on these soils for several years before fertilizer is required.

Base Saturation Ratio Recommendations

Some soil reports use base saturation ratios to develop recommendations for potassium, calcium and magnesium. This system is designed to result in ideal proportions of each nutrient in relation to the others. The ratios of these three nutrients are used as indicators of their availability. Crops can grow at a wide range of potassium-calcium-magnesium ratios. Crop response to these nutrients rarely occurs unless the soil test level indicates a deficiency. Many Ontario soils are naturally high in calcium and magnesium. As a result, the rates of potassium recommended in this system are often high and uneconomical. Striving to meet an exact ratio has little, if any, effect on crop yield.

Plant Analysis

Plant analysis measures the nutrient content within the plant tissue. This can be a useful addition to soil testing. Plant analysis results are compared against established normal ranges for the crop, indicating whether a specific nutrient is deficient. For some nutrients, this can indicate whether the soil nutrient supply is adequate for optimum growth. If soil levels are known to be adequate, plant analysis may indicate other problems that are reducing nutrient uptake.

The sufficiency ranges for nutrients in vegetable crop tissue are included in the commodity sections of Chapter 9, starting on page 67. When the nutrients are within the sufficiency range, increasing the nutrient concentration in the leaf is unlikely to result in increased crop growth. The objective of a good fertility program is to maintain tissue concentrations on the lower end of the range. Attempting to bring the nutrient analysis up to the higher end could possibly result in over-fertilization and may not be cost effective.

The sufficiency ranges provided in Chapter 9 are to be used as a reference and a guideline only. The ranges were adapted from *Knott's Handbook for Vegetable Growers*, 5th edition, by D.N. Maynard and G.J. Hochmuth.

Plant analysis is particularly useful for evaluating phosphorus, potassium, magnesium and manganese. It is also very useful in assessing the status of boron, copper, iron or molybdenum, as they do not have reliable soil tests. Plant analysis has not been very reliable for evaluating nitrogen and zinc.

Plant analysis has limitations. Expert help in interpreting the results is often needed. Plant analysis does not usually indicate the cause of a deficiency or the amount of fertilizer required for correcting it. The timing of plant analysis on many vegetable crops is difficult. Rapid growth and a relatively short growing season mean that yield loss may have already occurred by the time sample results are available. However, it is a valuable tool for diagnosing nutrient-related problem areas in the field for future corrective measures.

Sampling

Time of sampling has a major effect on the results of plant analysis. Nutrient levels within a plant vary considerably with its age and physiological stage. Recommended sampling stages have been developed for most vegetable crops. Results are difficult to interpret if samples are taken at times other than those recommended. The recommended sampling stages appear in the commodity sections in Chapter 9. If you suspect a plant is nutrient deficient, sample it as soon as a problem appears.

Take tissue samples from a problem area rather than from the entire field. Collect and submit a separate sample from an adjacent, non-affected part of the field for comparison purposes.

Take leaves from at least 20 plants distributed throughout the area chosen for sampling. Each sample should consist of at least 100 g (3.2 oz) of fresh material. For most crops, sample the most recently mature leaf from each plant. Very old and very young leaves often provide irregular test results.

Collect tissue samples into labelled paper bags. Plant tissues will rot if they are stored in plastic bags.

Avoid contaminating the sample with soil. Even a small amount of soil will cause the results to be invalid, especially for micronutrients.

Collect and submit a soil sample from both affected and non-affected areas to accompany the tissue sample. This soil sample can help address whether the nutrient deficiency is a result of limited soil availability or due to another contributing factor.

Sample Preparation

Deliver fresh plant samples directly to the laboratory. If this is not possible, dry them at a low temperature to prevent spoilage.

Table 1–3.
Soil pH at Which Lime Is Recommended for Ontario Field-Grown Crops

Crop	Soil pH Below Which Lime Is Recommended	Target Soil pH[1]
Coarse- and Medium-Textured Mineral Soils (sands, sandy loams, loams and silt loams)		
All crops not listed below	6.1	6.5
Corn, soybeans, winter rye, grass hay and pasture, turf, tobacco, established tree fruits and grapes	5.6	6.0
Potatoes	5.1	5.5
Blueberry, cranberry, rhododendron, azalea	No lime recommended	
Fine Textured Mineral Soils (clay and clay loams)		
Alfalfa, brassica crops, rutabaga	6.1	6.5
All crops not listed below or above	5.6	6.0
Corn, rye, grass hay, and pasture, tobacco, established tree fruits and grapes, potatoes	5.1	5.5
Blueberry, cranberry, rhododendron, azalea	No lime recommended	
Organic Soils (peats and mucks)		
All crops not listed below	5.1	5.5
Blueberry, cranberry, rhododendron, azalea	No lime recommended	

[1] Where a crop is grown in rotation with other crops requiring a high pH, lime the soil to the higher pH. Crops with significantly different pH requirements (e.g., potatoes and brassica crops) may not be a suitable rotation.

Take precautions to prevent contamination with dust or soil. Do not allow the samples to come into contact with brass, copper or galvanized (zinc-coated) metal.

Plant analyses may be obtained from several laboratories in Ontario. See Appendix C, *Accredited Soil-Testing Laboratories in Ontario*, on page 228. Tissue analysis is not an OMAFRA-accredited test.

Soil pH and Liming

Two of the most important values reported on the soil test are the soil pH and the buffer pH. These are important, because pH affects crop growth, nutrient availability and some soil-borne diseases. To correct soil acidity, ground limestone should be broadcast and worked into the soil at rates determined by a soil test. Table 1–3, *Soil pH at Which Lime Is Recommended for Ontario Field-Grown Crops*, above, shows the soil pH values below which lime is recommended and the "target" soil pH to which soils should be limed for different crops. In Ontario, most crops grow quite well at pH values higher than the target pH to which lime is recommended.

Table 1–4.
Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH

Ground limestone required — tonne/ha
(based on an Agricultural Index of 75)

Buffer pH	Target soil pH = 7.0[1]	Target soil pH = 6.5[2]	Target soil pH = 6.0[3]	Target soil pH = 5.5[4]
7.0	2	2	1	1
6.9	3	2	1	1
6.8	3	2	1	1
6.7	4	2	2	1
6.6	5	3	2	1
6.5	6	3	2	1
6.4	7	4	3	2
6.3	8	5	3	2
6.2	10	6	4	2
6.1	11	7	5	2
6.0	13	9	6	3
5.9	14	10	7	4
5.8	16	12	8	4
5.7	18	13	9	5
5.6	20	15	11	6
5.5	20	17	12	8
5.4	20	19	14	9
5.3	20	20	15	10
5.2	20	20	17	11
5.1	20	20	19	13
5.0	20	20	20	15
4.9	20	20	20	16
4.8	20	20	20	18
4.7	20	20	20	20
4.6	20	20	20	20

[1] Liming to pH 7.0 is recommended only for club-root control on brassica crops.

[2] Add lime if soil pH is below 6.1.

[3] Add lime if soil pH is below 5.6.

[4] Add lime if soil pH is below 5.1.

What is pH?

pH is a measure of the level of acidity or alkalinity in the soil. The pH scale ranges from 0 to 14 and reflects the hydrogen ion concentration in the soil. A pH value of 7.0 is neutral. Values below 7.0 are acidic. Those above 7.0 are alkaline or basic. On mineral soils, most vegetable crops grow well in a soil pH range from 6.0 to 7.5. A range of 5.0 to 6.0 is acceptable on muck soils. Maintaining soil within the appropriate pH range is important. Many crop nutrients become less available as the soil pH moves out of the ideal range. There is also the possibility for nutrient toxicity to occur on soils with pH values outside of the ideal range.

Table 1–5.
Lime Requirement Equations Based on Soil Buffer pH

pH to which soil is limed	Equation (based on lime with an agricultural index of 75)
7.0	$\text{Lime (t/ha)} = 334.5 - 90.79\,pH_B + 6.19\,pH_B^2$
6.5	$\text{Lime (t/ha)} = 291.6 - 80.99\,pH_B + 5.64\,pH_B^2$
6.0	$\text{Lime (t/ha)} = 255.4 - 73.15\,pH_B + 5.26\,pH_B^2$
5.5	$\text{Lime (t/ha)} = 37.7 - 5.75\,pH_B$

pH_B = pH in Shoemaker, McLean and Pratt (SMP) buffer

Raising pH

Soil pH is increased by broadcasting and incorporating ground limestone into the soil. How much lime is needed is determined by soil testing. Table 1–3, *Soil pH at Which Lime Is Recommended for Ontario Field-Grown Crops*, on page 4, shows the pH values below which lime is recommended and the target soil pH to which soils should be limed. In Ontario, most crops grow quite well at pH values higher than the target pH.

Buffer pH

Different soils with any one soil pH value (for example, a pH of 5.2) will require different amounts of lime to bring the soil pH to the desired level. The amount of lime required will depend chiefly on the clay and organic matter content of each soil. The soil pH is used to determine which soils need to be limed. A separate soil test, the buffer pH, determines the amount of lime required. For soils needing lime (based on soil pH) Table 1–4, *Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH*, left, may be used to determine the amount of lime required to reach the target soil pH values required for different crops.

The lime requirements in Table 1-4 are based on the equations presented in Table 1–5, *Lime Requirement Equations Based on Soil Buffer pH*, above, with values rounded to the nearest t/ha. A minimum recommendation was set at 1 t/ha and a maximum at 20 t/ha. More exact requirements or requirements to adjust soil pH to 7.0 may be calculated from the equations presented in Table 1–5.

Raising the Soil pH With Limestone

Soil pH is raised by applying either calcitic or dolomitic limestone. The carbonate in the limestone neutralizes the soil acidity. Calcitic limestone consists largely of calcium carbonate. Dolomitic limestone is a mixture of both calcium and magnesium carbonates.

Table 1–6. Example Calculation of the Fineness Rating of Limestone

Particle Size	% of sample		Effectiveness Factor		
Coarser than No. 10 sieve[1]	10	x	0.0	=	0
No. 10 sieve to No. 60 sieve	40	x	0.4	=	16
Passing through No. 60 sieve[2]	50	x	1.0	=	50
Fineness Rating				=	66

[1] A No. 10 sieve has wires spaced 2.0 mm apart.

[2] A No. 60 sieve has wires spaced 0.25 mm apart.

Whether you should use calcitic or dolomitic limestone depends on the magnesium level in the soil. Use dolomitic limestone on soils with a magnesium soil test of 100 or less. It is an excellent and inexpensive source of magnesium for acid soils. Use either calcitic or dolomitic limestone on soils with magnesium test results greater than 100. Limestone's effectiveness in adjusting soil pH depends on its neutralizing value and its fineness rating, or particle size.

Neutralizing Value

Neutralizing value is the amount of acid a given quantity of limestone will neutralize when it is totally dissolved. It is expressed as a percentage of the neutralizing value of pure calcium carbonate. A limestone that will neutralize 90% as much acid as pure calcium carbonate is said to have a neutralizing value of 90. In general, the higher the calcium and magnesium content of a limestone, the higher its neutralizing value.

Fineness Rating

Fineness rating, or particle size, also affects the neutralizing value of limestone. The higher the fineness rating, the more rapidly the limestone reacts with the soil pH. A fineness rating calculation for ground limestone is illustrated in Table 1–6, *Example Calculation of the Fineness Rating of Limestone*, above.

The Agricultural Index

The Agricultural Index combines the neutralizing value and the fineness rating of a limestone. It provides a way of comparing different limestone sources. For example, a limestone with a high agricultural index is worth proportionately more than limestone with a low index because it may be applied at a lower rate. A limestone's agricultural index is determined by the following formula:

$$\text{The Agricultural Index} = \frac{\text{neutralizing value x fineness rating}}{100}$$

Recommendations from the OMAFRA-accredited soil tests are based on limestone with an Agricultural Index of 75. When using a lime source with a different Agricultural Index, a specific rate of application may be calculated using the following equation:

$$\text{Limestone application rate from soil test} \times \frac{75}{\text{Agricultural Index of your limestone}} = \text{Rate of application of your limestone}$$

For example, assume the soil test recommends 9 t/ha of limestone. If the limestone source has an Agricultural Index of 90, the application rate should be 7.5 t/ha (9 x 75/90 = 7.5 t/ha).

The Agricultural Index does not provide information about magnesium content.

Effect of Tillage Depth

Lime recommendations presented in Table 1–4, *Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH*, on page 5, should raise the pH of the top 15 cm (6 in.) of a soil to the listed target pH. If the soil is plowed to a lesser or greater depth than 15 cm (6 in.), proportionately more or less lime is required to reach the same target pH. Where shallow tillage depths are used, more frequent applications of lower rates are recommended.

Lowering Soil pH

On soils with pH values below 6.5, it is possible to lower the pH and make the soil more acidic. This can be done by adding sulphur or ammonium sulphate. This may be desirable for some crops, such as potatoes, for scab control. However, it may not be suitable for rotation crops. It is not possible to change from a low pH to a more moderate pH each year. pH recommendations should be developed to meet the needs of all the crops in the rotation. If the soil pH is above 6.5, it is not practical to lower the soil pH because very large amounts of sulphur or ammonium sulphate will be required.

Nitrogen

Nitrogen is an important element for the growth and development of all crop plants. As a component of chlorophyll, it plays a vital role in photosynthesis. Nitrogen is also one of the building blocks for the formation of amino acids, protein and enzymes.

Nitrogen is naturally present in all soils. Soil microbes feed on crop residues and soil organic matter, releasing nitrogen into the soil. As soil organic matter levels increase, so do the levels of naturally available nitrogen. As a result, good soil management practices enhance a soil's natural fertility levels. Legumes, such as alfalfa, build soil fertility by capturing atmospheric nitrogen and releasing it into the soil as they decompose.

Visual Symptoms

Nitrogen deficiencies usually first appear on older leaves. These leaves will turn light green or yellow as nitrogen is relocated from older, less productive leaves to the newest growth. Cool weather in early spring often causes plants to develop a temporary nitrogen deficiency. This is usually due to poor growing conditions and slow root development, not necessarily a lack of nitrogen in the soil.

Nitrogen and the Environment

Soil nitrogen is in a constant state of change. Processes such as leaching and denitrification result in the loss of nitrogen from the soil. Denitrification occurs when the soil is waterlogged and anaerobic microbes convert nitrate and ammonia into nitrous oxide gasses. These gasses can contribute to air pollution and poor air quality and are approximately 100 times more potent as a greenhouse gas than carbon dioxide.

The nitrate form of nitrogen, while being readily available to plants, is also very water soluble. As a result, nitrates tend to move with the soil water, causing the potential for groundwater and surface water pollution.

When the amount of nitrogen supplied to the crop meets the crop's growth requirements, the risk of losses to the environment is greatly reduced. The potential for nitrogen loss is highest during the late fall and early spring. By applying nitrogen according to the crop's needs, the amount of residual nitrogen left over at the end of the season is minimal, leaving little potential for losses.

It is important to account for fertilizer, manure and other sources of nitrogen when assessing a crop's fertility requirements. Other management practices to reduce the risk of nitrate losses include:

- growing cover crops
- timing nitrogen applications close to crop nitrogen uptake
- reducing total nitrogen applications

For more information on the nitrogen cycle and its role in the environment, see OMAFRA Publication 611, *Soil Fertility Handbook*.

Nitrogen Recommendations

Nitrogen fertilizer recommendations for vegetable crops are developed from field research trials conducted in Ontario. Recommended rates are presented under the heading *Fertility* in the individual commodity sections in Chapter 9, *Crop Management Recommendations*, starting on page 67.

Nitrogen fertilizer rates should be decreased if manure is applied or if the previous crop contained legumes such as alfalfa or red clover.

Pre Side-Dress Nitrogen Test

The pre side-dress nitrogen test (PSNT) is a tool that can help assess the level of plant-available nitrate-nitrogen present in the soil during the growing season. Developed for use in field corn production, this test can aid in determining additional fertilizer requirements.

Taking the soil sample:

- Nitrate-nitrogen soil samples are taken to a soil depth of 12 in. (30 cm).
- Sample approximately 1 week prior to the intended application. Side-dressing normally coincides with the start of a crop's rapid growth phase.
- Collect soil cores from representative areas of the field. Sample problem areas separately.
- Thoroughly mix the soil from approximately 20–25 cores.
- Package approximately 500 g of soil in a clean plastic bag.
- Chill or freeze the sample immediately. If the sample cannot be delivered to the lab in a chilled or frozen condition, allow it to air dry on a clean plastic sheet for 1–2 days prior to shipping. Microbial activity can drastically change the nitrate-nitrogen content, if the samples are not handled properly.

The PSNT results are expressed in parts per million (ppm) of nitrate-nitrogen. To convert this number into lb/acre, multiply by 4. For example, a nitrate-nitrogen test reading 15 ppm represents 60 lb/acre. Research in field corn has shown that there will be minimal yield response to additional fertilizer nitrogen if the PSNT values are greater than 30 ppm.

Keep in mind that the PSNT was developed for use in field corn production and has not been thoroughly researched for use with horticultural crops. The PSNT is a tool. It can give growers an indication of the nitrate-nitrogen content in the soil at one given point in time. Where PSNT values are high, growers may be able to reduce the side-dress nitrogen fertilizer rate. For vegetable crops, nitrate-nitrogen sampling should not entirely replace current OMAFRA fertility recommendations or grower experience.

Sources of Nitrogen

Synthetic Fertilizer

The most common sources of fertilizer nitrogen are outlined in Table 1–7, *Fertilizer Materials: Primary Nutrients*, right. Generally speaking, no one source of nitrogen is superior to the others. Cost, crop management and ease of application will largely determine the selection of one source over another.

Short-season crops, such as lettuce and leafy greens, may prove the exception to this rule. If the cropping season is less than 4–6 weeks, consider selecting a more rapidly available nitrogen source, such as calcium nitrate or calcium ammonium nitrate.

With some early-planted vegetables, the use of nitrogen sources such as urea may actually help prevent leaching losses during the early part of the growing season when soil temperatures are low. Under cool soil conditions, it takes 3–6 weeks for the urea to convert into the plant-available ammonium and nitrate forms of nitrogen. As only nitrates are leached from the soil, urea and ammonium fertilizers are less susceptible to losses during early spring rain events when the soils are cool. By the time the nitrogen conversion has occurred, the crop is entering its rapid growth phase. Leaching is less likely to occur when the crop is rapidly growing. Nitrogen conversions are very temperature dependent. As the soil heats up, these conversions occur much more rapidly.

Products That Modify the Release of Nitrogen

Slow-release fertilizers and nitrification inhibitors are a recent addition to the marketplace. Popular in the turf industry, "slow-release" fertilizers have been coated with sulphur to control the release of the nitrogen over an extended period of time. Nitrification inhibitors are added to the fertilizer to help delay the chemical conversion of urea into the plant-available forms.

Table 1–7.
Fertilizer Materials:
Primary Nutrients

Nitrogen Materials	**Form**	**% Nitrogen (N)**
Ammonium nitrate	Dry	34
Urea	Dry	46
Ammonium sulfate	Dry	20
Calcium ammonium nitrate	Dry	27
Calcium nitrate	Dry	15.5
Aqua ammonia	Liquid[1]	20
Urea ammonium nitrate (UAN)	Liquid	28
Anhydrous ammonia	Liquid	82
Phosphate Materials		**% Phosphate (P_2O_5)**
Single superphosphate	Dry	20
Triple superphosphate	Dry	46
Monoammonium phosphate (11-52-0)	Dry	50 to 52
Ammonium polyphosphate (10-34-0)	Liquid	34
Diammonium phosphate (18-46-0)	Dry	46
Potash Materials		**% Potash (K_2O)**
Muriate of potash	Dry	60 to 62
Sulfate of potash	Dry	50
Sulfate of potash magnesia (11% Mg)	Dry	22
Potassium nitrate (13-0-44)	Dry	44

[1] Liquid under pressure.

The behaviour of nitrogen in the soil is largely impacted by soil moisture and temperature. Depending on the weather conditions, the delayed release of these products may not necessarily coincide with a vegetable crop's peak nitrogen demand, especially when short-season vegetables are being grown. These materials may cost significantly more than traditional fertilizer sources.

Manure

The value of manure in vegetable crop production is often underestimated. In addition to nitrogen, phosphorus and potash, manure contains many secondary nutrients and micronutrients. Manure also contains valuable organic matter that helps build and maintain soil structure.

Fifty to sixty per cent of the nitrogen available in manure is available to the crop during the first growing season following application. The remaining organic nitrogen becomes available in small, diminishing quantities in the succeeding years. Up to 10% of the manure organic nitrogen can be available for the following year's crop. From solid manure, this is typically 7–10 lb of nitrogen.

Table 1–8. Average Amounts of Available Nutrients for Different Types of Manure

Nutrient values based on average analysis results for over 3,000 samples[1]. There are large variations between manures, so a manure analysis is your best guide to nutrient availability.

Manure	% Average Dry Matter	Available[2] N Spring	Available[3] P_2O_5	Available[4] K_2O
		kg/1,000 L (lb/1,000 gal)		
Liquid dairy	8.4	1.8 (18)	.77 (7.7)	2.6 (26)
Liquid hog	3.7	2.7 (27)	1.2 (12)	1.9 (19)
Liquid poultry	10.5	5.8 (58)	2.8 (28)	3.2 (32)
		kg/tonne (lb/ton)		
Solid poultry	55.3	10.5 (21)	11 (22)	13.4 (26.8)
Solid dairy	25.0	1.8 (3.6)	1.5 (3.0)	5.2 (10.5)
Composted dairy	38.3	2.9 (5.8)	2.6 (5.2)	11.8 (23.8)
Solid beef	28.4	1.9 (3.8)	2.1 (4.3)	6.1 (12.2)
Sheep	33.8	2.9 (5.9)	2.6 (5.2)	8.3 (16.7)
Horse	37.4	1.3 (2.6)	1.4 (2.8)	4.6 (9.3)

[1] Data from manure analysis provided from Ontario Labs collected between 1992 and 2007.

[2] Nitrogen based on spring application, incorporated within 24 hr.

[3] Phosphate from manure or biosolids is assumed to be 40% as available in the year of application as that in commercial fertilizer (another 40% of the phosphorus is available the following year).

[4] Potassium from manure is assumed to be 90% as available in the year of application as that in commercial fertilizer.

Where manure is applied regularly to the same field, there may be a significant amount of residual nitrogen available for a crop.

The quantities of nutrients contained in manure vary from farm to farm. The type of livestock, ration, bedding, added liquids and storage system all affect the final nutrient analysis. Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, above, lists the approximate amount of crop-available nitrogen contained in manure. A more detailed list is also available in OMAFRA's N-MAN program. A manure analysis, available from several laboratories in Ontario, can provide a more accurate assessment of the nutrients contained in a specific source of manure. See Appendix C, *Accredited Soil-Testing Laboratories in Ontario*, on page 228, for a list of laboratories providing this service.

For liquid manure, an application goal of 60%–75% of the nitrogen requirements for a corn crop is reasonable. With solid manure, the release of nitrogen is much less predictable due to the high carbon content of the bedding material. Plan on budgeting for no more than 50% of the crop's nitrogen requirement from solid manure.

Use manure responsibly:

- Avoid spreading on frozen or snow-covered ground.
- Avoid making applications, when the potential for runoff is high.
- Tillage prior to applying liquid manure will help break up soil cracks and large pores, preventing the movement of manure into the groundwater.
- Inject or incorporate the manure to help prevent the loss of ammonia gas into the atmosphere, leaving more nitrogen in the soil, available for the crop.
- When storing or piling manure in the field, follow the management practices outlined in the OMAFRA Factsheet, *Temporary Field Storage of Solid Manure or Prescribed Materials*, Order No. 05-009.

Manure and Food Safety

Fruit and vegetable crops can become contaminated in the field if they come into contact with pathogens that cause human illness. These pathogens may come from manure and manure-based composts. The lifespan of these pathogens in manure is not well known. Proper composting of manure, which results in heating to a specific temperature for a specific period of time, will reduce the level of most pathogens. For most vegetable crops, manure applications less than 120 days before harvest are not recommended. For more information on food safety concerns in vegetable crops, see the section *On-Farm Food Safety*, on page 45.

Legumes

Legume crops are able to capture atmospheric nitrogen from the air. As the residue from previous legume crops decomposes, this nitrogen becomes available for the subsequent crops. When vegetables follow alfalfa hay or a legume cover crop, such as red clover, the rate of fertilizer nitrogen should be decreased to compensate for the amount of nitrogen supplied by the legume. The recommended adjustments can be found in Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

Biosolids

Biosolids from off-farm sources can be a useful source of nutrients and organic matter. Guidelines for their use are available from OMAFRA and the Ministry of the

Table 1–9. Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down

Type of Sod	For All Crops, Deduct From N Requirement kg N/ha
Less than 1/3 legume	0
1/3 to 1/2 legume	55
1/2 or more legume	100
Clover cover crop	45
Soybean and field bean residue	0

Environment (MOE). A Certificate of Approval for land application is required and is available from MOE. An analysis of nutrients applied should be given by the applicator to the landowner whenever biosolids are applied.

Sewage sludge from municipal sewage treatment plants may not be applied to vegetable-producing land less than 12 months before harvest.

Always consult with your processor, packer, broker or buyer before applying sewage sludge on ground intended for vegetables anywhere in the rotation.

Nitrogen Application Methods

Most nitrogen fertilizers readily dissolve in the soil water and move easily through the soil to the plant roots. For this reason, placement of nitrogen is rarely a concern. The bulk of a crop's nitrogen requirement can be broadcast prior to planting or side-dressed.

Side-Dressing

Nitrogen-use efficiency can be enhanced in many vegetable crops with a split application. A portion of the nitrogen requirement is applied prior to planting as a broadcast, banded or transplant water application. The remainder is applied between the rows as the crop enters its rapid growth phase. This practice helps minimize leaching and prevents fruiting vegetables from developing too much vegetative growth.

Banding

Relatively low amounts of nitrogen applied at the time of planting can help promote early-season growth. By banding the fertilizer 2 in. (5 cm) beside and 2 in. (5 cm) below the seed, the fertilizer is readily available to the emerging seedling. This practice works well when used in combination with side-dress applications. When banding, select fertilizer rates with caution. A high concentration of fertilizer in the band may damage the roots of the young seedlings.

See each individual commodity section in Chapter 9 for specific recommendations regarding the maximum rates of nitrogen to be applied at planting.

Starter Solutions and Seed-Placed Nitrogen

Water soluble or liquid fertilizers applied with the planter water may promote faster field establishment of transplanted vegetable crops, especially in cold soils. Under dry soil conditions, the amount of nitrogen in the starter should be reduced or eliminated. See the individual crops sections in Chapter 9, *Crop Management Recommendations*, starting on page 67, for specific recommendations for safe rates of starter fertilizers.

Seed placed fertilizers are generally not recommended for use with vegetable crops.

Fertigation

Where crops are grown under fertigation, apply approximately half of the crop's total nitrogen requirement prior to planting. The remainder can be injected through the fertigation system.

The objective of a fertigation system is to match nutrient applications with crop requirements and uptake. This can be achieved by applying small amounts of fertilizer regularly, as the crop develops. The weekly application rate usually increases as crop growth and demand increase. Once harvest begins, rates can level off or even decrease. Recommended fertigation application rates for tomatoes, peppers and vine crops appear in the commodity sections of Chapter 9.

Do not use fertilizers containing calcium, phosphate or sulphate, as these elements may plug the emitters.

For more information on fertigation, see Chapter 3, *Water Management*, on page 27.

Phosphorus

Like nitrogen, phosphorus is an important component of photosynthesis and the development of enzymes and protein. It also plays an important role in cell division and in the creation and transport of sugars and starches.

Soil phosphorus levels across Ontario can be quite varied. However, many coarse sandy-loam soils often contain high levels of phosphorus. Former tobacco land and soils

Avoid Fertilizer Burn!

Many nitrogen and potash fertilizer materials contain high amounts of salts. If a germinating seedling or young transplant comes into contact with a concentrated fertilizer band, the tender roots may become seriously damaged. For this reason, ensure that the correct fertilizer and the appropriate rate are selected for each application.

Urea has a relatively high salt index. It is not suitable for use in starter fertilizers or banded applications. Urea is an effective, economical source of nitrogen for broadcast applications. However, if dry soil moisture conditions exist at the time of planting, urea burn may occur on coarse sandy-loam soils. Under dry soil conditions, consider using a different nitrogen source.

Anhydrous ammonia also has a relatively high salt index. It is an effective source for side-dress applications. Do not apply anhydrous ammonia to vegetable crops prior to planting.

Ensure that starter or transplant fertilizers contain only as much nitrogen as necessary to get the crop started. Fertilizers containing more than half as much nitrogen as phosphate frequently contain urea and may cause crop damage. See the individual crops sections in Chapter 9 for specific recommendations for safe rates of starter fertilizers.

with a history of regular manure applications often have phosphorus soil test ratings of Low Response (LR) to No Response (NR). These soils are capable of producing high-yielding vegetable crops with little or no additional phosphorus fertilizer.

Applications of additional phosphorus on low response soils may negatively impact the crop's ability to remove zinc and iron from the soil. Where phosphorus levels are high, zinc and iron deficiencies may occur.

Visual Symptoms

Phosphorus deficiency symptoms usually develop on the older leaf tissue first. It causes these leaves to develop a purplish-red colour. This may be more noticeable on the underside of the leaves. Severe deficiencies may also cause the leaf tips to die back. Cool, wet soil conditions often trigger phosphorus deficiencies. For early-planted vegetable crops, use a starter fertilizer to deliver the required phosphorus directly to the root zone.

Phosphorus in the Environment

Phosphorus binds tightly to soil particles. When erosion deposits phosphorus-rich soil into drains and water courses, it can result in poor water quality.

Avoid making additional phosphorus applications to soils testing in the Rare Response (RR) or No Response (NR) categories. If phosphorus is required to promote early-season growth, use low rates applied in a band or as a starter fertilizer.

Consider leaving a 3-m (10-ft) grassed buffer zone around all creeks, streams and ponds. The grass will help reduce erosion and act as a natural filter for runoff entering the watercourse.

Farms that are required to complete a nutrient management plan must establish a permanent vegetated buffer adjacent to any surface water, with a minimum width of 3 m (10 ft) prior to any nutrient application.

Where phosphorus soil test results are greater than 30 ppm, use the phosphorus index to determine separation distances from surface water sources. The phosphorus index uses a series of five factors, including field slope, length of slope, soil drainage class and soil texture to determine an appropriate rate and separation distance from surface water. For details on the phosphorus index, see the OMAFRA Factsheet, *Determining the Phosphorus Index for a Field,* Order No. 05-067.

Phosphorus Recommendations

In Ontario, phosphate fertilizer recommendations are based on OMAFRA-accredited soil tests. Soil testing is the most accurate method of determining the amount of phosphate required for healthy and productive crop growth.

Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, and Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, outline crop-specific recommendations.

Only use these recommendation tables with OMAFRA-accredited sodium bicarbonate (Olsen) soil tests. Non-accredited tests may use different procedures, resulting in inaccurate recommendations if used with the OMAFRA tables. Fertilizer rates in this table are designed to produce high economic yields when accompanied by good or above average management.

Table 1–10.
Phosphorus Requirements: Vegetables on Mineral Soils

Phosphorus Soil Test (mg P/ L of soil)[1]	Rating*	Phosphate (P_2O_5) Required kg/ha								
		Beans (lima & snap) Peas	Radishes	Sweet corn Asparagus (established)	Sugarbeets	Beets Carrots Lettuce Onions Parsnips Rutabagas Spinach Horseradish	Potatoes	Cucumbers Muskmelons Pumpkins Squash Tomatoes[2] Watermelons	Celery Rhubarb	Broccoli[3] Brussels sprouts[3] Cabbages[3] Cauliflower[3] Eggplant[2] Peppers[2] Asparagus (nursery & new plantings)
0–3	HR	80	80	110	150	180	200	230	230	270
4–5		60	70	100	140	170	200	230	230	260
6–7		50	60	90	140	170	190	220	220	250
8–9		40	60	70	130	160	190	220	220	240
10–12	MR	30	50	50	130	160	180	210	220	230
13–15		20	50	20	120	150	170	190	210	220
16–20	LR	0	40	20	100	140	160	170	190	200
21–25		0	40	20	90	120	140	140	160	170
26–30	RR	0	30	20	70	100	120	110	140	140
31–40		0	30	0	50	80	90	80	110	110
41–50		0	20	0	30	50	50	50	80	80
51–60		0	0	0	0	30	30	30	50	50
61–80	NR	0	0	0	0	0	30	0	0	0
80+		0	0	0	0	0	30	0	0	0

* HR = high response MR = medium response LR = low response RR = rare response NR = no response

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[1] Sodium bicarbonate (Olsen) extraction method.

[2] For transplanted tomatoes, peppers and eggplants, apply a starter solution, such as 1 L of 10-34-0 per 100 L of water, or 1 L of 6-24-6 per 75 L at planting.

[3] For transplanted broccoli, Brussels sprouts, cabbages and cauliflower, if no insecticide is used in the planting water, apply a starter solution high in nitrogen such as 20-20-20 at 1 kg/200 L. Under high temperatures and in dry, sandy soils, use half the concentration of fertilizer.

Where a soil test is not available, use the following guidelines to obtain a rough estimate of requirements from these tables:

- If the field has been fertilized regularly for a number of years, or heavily in recent years, use one of the rates recommended for the medium response (MR) soil test rating.
- If the field has received little fertilizer in the past, use one of the rates recommended for a high response (HR) soil test rating.

Soils testing rare response (RR) or no reponse (NR) for phosphorus contain more plant-available phosphorus than required for most crops.

Do you use manure? Don't forget to decrease your fertilizer rate accordingly. For more details, see Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9.

Sources of Phosphorus

Synthetic Fertilizers

The most common sources of fertilizer phosphorus are outlined in Table 1–7, *Fertilizer Materials: Primary Nutrients*, on page 8.

Mono-ammonium phosphate (MAP) is one of the most effective sources of fertilizer phosphorus. In addition to the phosphorus, it contains 11% nitrogen (ammonium.) The presence of nitrogen can help improve the plant's

Table 1–11.
Phosphorus and Potassium Requirements: Vegetables on Muck Soils

Phosphorus					Potassium				
		Phosphate required kg P_2O_5/ha					Potash required kg K_2O/ha		
Phosphorus Soil Test[1] mg P/ L of soil	Rating*	Beets Broccoli[3] Brussels sprouts[3] Cabbages[3] Carrots Cauliflower[3]	Lettuce Onions[4] Parsnips Potatoes Radishes Spinach	Celery	Potassium Soil Test[2] mg K/ L of soil	Rating*	Broccoli Brussels sprouts Cabbages Cauliflower	Carrots Celery Onions Parsnips Potatoes	Beets Lettuce Radishes Spinach
0–3		100		120	0–15		200	230	100
4–5	HR	100		120	16–30	HR	190	220	100
6–7		100		120	31–45		170	210	90
8–9		100		120	46–60		150	200	80
10–12		90		120	61–80		120	170	60
13–15		90		110	81–100		90	150	40
16–20	MR	80		100	101–120	MR	70	120	30
21–25		70		90	121–150		50	80	20
26–30		60		80	151–180		40	40	20
31–40		50		70	181–210	LR	0	0	0
41–50	LR	30		50	211–250	RR	0	0	0
51–60		20		40	250+	NR	0	0	0
61–80	RR	0		0					
80+	NR	0		0					

* HR = high response MR = medium response LR = low response RR = rare response NR = no response

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[1] Sodium bicarbonate (Olsen) extraction method

[2] Ammonium acetate extraction method.

[3] For transplanted broccoli, Brussels sprouts, cabbages and cauliflower, if no insecticide is used in the planting water, apply a starter solution high in nitrogen, such as 20-20-20 at 1 kg/200 L. Under high temperatures and in dry, sandy soils, use half the concentration of fertilizer.

[4] If maturity of onions is a problem on organic soils less than 40 cm deep, additional phosphate may be required.

ability to absorb phosphorus. When using MAP, be sure to decrease the amount of nitrogen fertilizer used accordingly. Excess nitrogen, especially in fruiting vegetables, may result in too much leaf growth and decreased fruit yields.

Manure

When properly applied, manure is an excellent, inexpensive source of phosphorus. It also supplies the soil with valuable organic matter and micronutrients. Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, provides the approximate amount of crop-available phosphorus contained in manure.

Unlike nitrogen, the phosphorus in manure can be held by the soil over a considerable period of time. The application of large quantities of manure over time may result in a build-up of phosphorus in the soil. The long-term impact of manure applications is best estimated by soil testing. Avoid making heavy manure applications on soils testing rare response (RR) or no response (NR) for phosphorus (see the section *Phosphorus in the Environment*, on page 11).

Phosphorus Application Methods

Phosphorus fertilizers are commonly broadcast prior to planting. Phosphorus does not move within the soil water. A broadcast application will help ensure that adequate phosphorus levels are evenly distributed throughout the crop's rooting zone. Side-dress applications of phosphorus are not generally recommended.

Starter Fertilizer

Research has shown that phosphorus availability and root growth are reduced during cool soil conditions. As a result, many early-season vegetable crops benefit greatly from having small amounts of phosphorus applied to the rooting zone at seeding or transplanting. For crops planted later in the season, under more favourable soil conditions, there is little benefit to adding extra phosphorus at the time of planting. See Chapter 9, *Crop Management Recommendations*, starting on page 67, for more specific instructions regarding the use of starter fertilizers.

Fertigation

Many common forms of phosphorus are not suitable for use in fertigation systems. Most phosphate fertilizers will form salts when mixed with other nutrients. These salts will plug the emitters, rendering the whole system useless. Water-soluble forms of phosphorus have been developed for the greenhouse industry. However, in field conditions, there is no yield advantage associated with the application of phosphorus through drip irrigation. Soil applications remain the most cost-effective method of delivering phosphorus to the crop.

Potassium

Potassium (K) is an important component of plant cells. It also influences the uptake of water by the roots and plays a role in both respiration and photosynthesis. The sugar and starch content of crops like potatoes and tomatoes may be affected by potassium levels.

Most crops require equal amounts of potassium and nitrogen. Excessive potash applications may negatively impact the crop's ability to remove calcium and magnesium from the soil. Where soil potassium levels are high, calcium and magnesium deficiencies may occur.

Visual Symptoms

Potassium deficiency usually appears on the older leaves first. It can cause a yellowing or burning of the leaf margins. In tomatoes, low potassium levels have been associated with yellow shoulders on ripe fruit. In other fruiting vegetables, severe potassium deficiencies may result in misshapen fruit and increased levels of fruit abortion. Insufficient levels of potassium may reduce the shelf-life of many vegetable crops.

Potassium Recommendations

Crop-specific recommendations are outlined in Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, and Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

These recommendation tables should only be used with OMAFRA-accredited ammonium acetate extraction soil tests. Non-accredited tests may use different procedures, resulting in inaccurate recommendations if used with the OMAFRA tables. Fertilizer rates in this table are designed to produce high economic yields when accompanied by good or above average management.

Where a soil test is not available, use the following guidelines to obtain a rough estimate of requirements from these tables:

- If the field has been fertilized regularly for a number of years, or heavily in recent years, use one of the rates recommended for the medium response (MR) soil test rating.
- If the field has received little fertilizer in the past, use one of the rates recommended for a high response (HR) soil test rating.

Some clay and clay loam soils are naturally high in potassium and do not require any potash fertilizers. Only a soil test can adequately determine potash requirements.

Sources of Potassium

Synthetic Fertilizers

The most common sources of fertilizer potash are outlined in Table 1–7, *Fertilizer Materials: Primary Nutrients*, on page 8.

Manure

Manure is an excellent, inexpensive source of potassium. It also supplies the soil with valuable organic matter and micronutrients. Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, lists the approximate amount of crop-available potash contained in manure.

Unlike nitrogen, the potassium found in manure can be held by the soil over a considerable period of time. The application of large quantities of manure over time may result in a build-up of potash in the soil. The long-term impact of manure applications is best estimated by soil testing.

Potash Application Methods

Potash fertilizers are commonly broadcast prior to planting. Where a drip irrigation system is being used, a significant portion of the fertilizer may be applied as fertigation.

Fertigation

Where crops are grown under fertigation, apply approximately half of the potash requirement prior to planting. The remainder can be injected through the fertigation system.

Table 1–12.
Potassium Requirements: Vegetables on Mineral Soils

Potassium Soil Test[1] (mg K/ L of soil)	Rating*	Potash (K_20) Required kg/ha									
		Radishes	Beans (snap & lima) Peas	Sweet corn	Sugarbeets[2]	Tomatoes (paste & fresh market) Cucumbers Muskmelons Pumpkin Squash Watermelons	Beets Carrots Lettuce Onions Parsnips Potatoes Spinach Horseradish	Broccoli Brussels sprouts Cabbages Cauliflower Eggplant Peppers	Celery Rhubarb Rutabagas[3]	Asparagus	Tomatoes[3] (whole pack)
0–15	HR	60	120	170	180	230	230	270	340	420	660
16–30		60	110	160	170	220	220	250	330	400	640
31–45		50	90	140	160	200	210	230	310	360	600
46–60		50	80	110	140	180	190	200	280	320	560
61–80	MR	40	60	80	120	140	160	170	250	280	480
81–100		30	40	50	90	100	130	130	200	250	400
101–120		30	30	30	70	70	100	100	150	220	340
121–150		20	0	0	20	50	80	80	90	190	300
151–180		20	0	0	0	40	50	50	50	160	280
181–210	LR	0	0	0	0	0	0	0	0	130	140
211–250	RR	0	0	0	0	0	0	0	0	80	70
250+	NR	0	0	0	0	0	0	0	0	0	0

* HR = high response MR = medium response LR = low response RR = rare response NR = no response

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[1] Ammonium acetate extraction method.

[2] Excess application of potassium will lead to luxury consumption by the sugarbeet plant. This has a negative effect upon clear juice purity.

[3] For rutabagas and tomatoes on soils with magnesium tests less than 100, the required amount of potash is adjusted downward from the amounts shown in this table to a minimum of 50% at 50 ppm Mg.

Recommended application rates for fertigated tomatoes, peppers and vine crops appear in the commodity sections of Chapter 9.

For more information, see the section *Fertigation*, on page 10, and Chapter 3, *Water Management*, on page 27.

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Calcium

Calcium is a vital component of cell walls and is involved in the metabolism and formation of the cell nucleus. Calcium pectate in the cell walls provides a physical barrier to disease entry. Calcium does not move readily within the plant.

Visual Symptoms

Calcium deficiencies may result in the death of the plant's growing point. It may also cause the blossoms and buds to drop prematurely.

Fertilizer Recommendations

Calcium deficiencies rarely occur in vegetables grown on soils with a pH of 6.0–7.5. Foliar applications may be warranted on coarse sandy loam soils, where the pH is at the low end of this range. See Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Management Notes

Calcium-related disorders may occur in some crops (e.g., blossom-end rot in tomatoes, blackheart in celery or tipburn in lettuce and cabbage). Calcium enters the plant through the transpiration stream. If the water supply is limited, calcium tends to accumulate in the large leaves where the water requirement is greatest. Under these conditions, the dissolved calcium bypasses the fruit and developing leaves, which have lower transpiration rates.

Several cultural management practices will reduce the occurrence of calcium-related disorders. Efficient nitrogen use will help prevent excessive vegetative growth. Good soil management practices ensure good root growth, promoting both water and nutrient uptake. Timely irrigation will help maintain a steady supply of calcium throughout the plant.

Table 1–13.
Application Rates for Magnesium, Calcium and Micronutrients

A number of micronutrients are available as chelates, with various formulations and nutrient contents. Check the product labels. The effective use rate for chelated products is the same as for other formulations.

	Soil Applied[1]				Foliar Applied	
Nutrient	**Nutrient kg/ha**	**Product kg/ha**	**Source**	**% Composition**	**Nutrient kg/1,000 L**	**Product kg/1,000 L**
Calcium (Ca)[2]	–	–	calcium chloride	36% Ca	1.9	5.0
	–	–	calcium nitrate	19% Ca	1.9	10.0
Magnesium (Mg)	120–260	2 t/ha	dolomitic limestone	6–13% Mg	–	–
	30	285	epsom salts	10.5% Mg	1.9	18
	30	270	sulphate of potash magnesia	11% Mg	–	–
Boron (B)	1.0–3.0	–	sodium borate	12–21% B	0.1–0.3	–
Copper (Cu)	7.0–14.5	28–60	copper sulfate	13–25% Cu	0.5–1.5	2–6
	–	–	copper chelates	5–13% Cu	0.5–1.5	–
Manganese (Mn)[3]	–	–	manganese sulfate	28% Mn	0.5–1.0	1.8–3.6
	–	–	manganese chelates	5–12% Mn	0.5–1.0	–
Molybdenum (Mo)	–	–	sodium molybdate	39% Mo	0.1–0.25	0.25–0.6
Zinc (Zn)	4–14	11–33	zinc sulfate	36% Zn	0.6	1.6
	4–14	–	zinc oxysulfate	18–36% Zn	–	–
	–	–	zinc chelate	9–14% Zn	0.6	–

[1] Double rates for muck soil, except dolomitic limestone.
[2] For blackheart of celery.
[3] For onions, use 1.5–2.75 kg Mn/1,000 L.

Magnesium

Magnesium is an essential part of chlorophyll. It also aids in the formation of sugars, oils and fats.

Visual Symptoms

Magnesium deficiency usually appears on the older leaves first. The leaf tissue between the veins turns yellow, while the veins remain green. Severe deficiencies will cause the leaf margins to curl.

Fertilizer Recommendations

Apply magnesium according to Table 1–14, *Magnesium Soil Test Ratings and Interpretations for All Crops*, right. See also Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, above.

Management Notes

Excessive potassium applications may induce a magnesium deficiency. If the soil pH is below 6.5, the most effective and economical means of supplying magnesium is with applications of dolomitic lime. If the pH is above 6.5, and the soil test result is 20 or below, magnesium can be supplied by either magnesium sulfate or sulfate of potash magnesia. For tomatoes and rutabagas on soils with magnesium tests of less than 100, the amount of potash recommended should be adjusted downward to a minimum of 50% at a magnesium test of 50.

Table 1–14.
Magnesium Soil Test Ratings and Interpretations for All Crops

Soil Magnesium[1] mg/L of soil (ppm Mg)	Rating	Recommendation
Below 20	HR	Magnesium should be applied for all crops. If pH is below 6.5, apply dolomitic lime. At higher pH values, apply 30 kg soluble magnesium (Mg) per hectare. Potash applications in excess of those recommended by soil test will increase the probability of Mg deficiency.
20–39	MR	If lime is required, use dolomitic. Magnesium is recommended if potassium soil test is above 250. Potash applications in excess of those recommended by soil test will increase the probability of magnesium deficiency.
40–100	MR	If lime is required, use dolomitic.
100+	LR	If lime is required, either dolomitic or calcitic may be used.

[1] 1 M ammonium acetate extraction method.

Sulphur

Sulphur is an important component of chlorophyll. It aids in seed production and is involved in nitrogen fixation in legumes. Sulphur adds flavour, colour and distinctive odours to several crops including brassica crops, onions, garlic and horseradish.

Visual Symptoms

Sulphur deficiency is very similar to nitrogen deficiency. Affected plants are often stunted and have pale foliage. Sulphur deficiency may delay maturity. Nitrogen deficiency usually appears on the older leaves first, while sulphur deficiency will effect the entire plant.

Fertilizer Recommendations

There is no OMAFRA-accredited soil sulphur test. Soil sulphur levels fluctuate over the course of the growing season depending on soil temperature, moisture and organic matter. Historically, sulphur was a component of many synthetic fertilizers. Modern production methods have removed much of the sulphur found in fertilizer. Nevertheless, many Southwestern Ontario farms still receive considerable amounts of sulphur in the form of acid rain. Each year, 8–13 kg/ha (7–12 lb/acre) of sulphur are deposited in rainfall.

Deficiencies occasionally occur on coarse, sandy-loam, low pH soils. On these soils, apply calcium sulphate. Improving soil organic matter will also help increase soil sulphur levels. Many livestock manures also contain significant amounts of sulphur.

Micronutrients

Micronutrients include boron, copper, iron, manganese, molybdenum and zinc. Plants use these elements in smaller amounts than the major nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium. But they are still very crucial to a plant's overall nutrition.

Micronutrients are usually found in much lower levels in the soil than macronutrients. Soil pH, organic matter, clay content and mineralogy can influence the micronutrient soil test. This makes estimating micronutrient availability less reliable than macronutrient evaluation.

Which to Choose: Soil or Foliar Fertilizers?

Both soil and foliar fertilizers have a role to play in vegetable crop production. The major nutrients (nitrogen, phosphorus, potassium, calcium and magnesium) are required in relatively high amounts for crop growth. Foliar uptake occcurs though the leaf's cuticle and the stomata. The amount of nutrients that can enter the plant through these means is quite limited, and increasing the application rates may lead to crop injury. As a result, soil application is almost always the most efficient and economical method of getting the major nutrients into the plant.

Micronutrients, which are required by the crop in much lower quantities, can often be efficiently delivered through foliar applications, especially when soil conditions impact the nutrient's availability. Depending on the micronutrient and the timing at which the deficiency is identified, either soil-applied or foliar fertilizers may be recommended. Specific recommendations regarding application methods are discussed in the individual micronutrient sections, starting on page 17.

Foliar-applied nutrient uptake can be improved through the timing of the application and the use of surfactants. Younger leaves generally have a less well-developed cuticle and are able to take in more of the nutrient. Early-morning applications may favour foliar uptake. Avoid applying foliar nutrients during the heat of the day when leaves will dry quickly; this will reduce their effectiveness. Ensure good leaf coverage, particularly on the underside.

Crop Response to Micronutrient Fertilizers

Crops vary in their response to micronutrients. Highly responsive crops will often respond to additional micronutrients if the soil micronutrient concentration is low. Medium-responsive crops are less likely to respond, and low-responsive crops do not usually respond to fertilizer additions, even at low soil micronutrient levels.

Table 1–15, *Response of Crops to Micronutrient Fertilizers*, on page 18, outlines the response of various vegetable crops to micronutrient fertilizers. A high rating does not mean the crop always needs additional micronutrients. Response to any given nutrient only occurs when the soil is already low in that nutrient.

Table 1–15.
Response of Crops to Micronutrient Fertilizers[1]

Crop	Mn	B	Cu	Zn	Mo	Fe
Asparagus	Low	Low	Low	Low	Low	Med
Beans, snap	High	Low	Low	High	Med	High
Beets, table	High	High	High	Med	High	High
Broccoli	Med	High	Med		High	High
Cabbages	Med	Med	Med	Low	Med	Med
Carrots	Med	Med	Med	Low	Low	
Cauliflower	Med	High	Med		High	High
Celery	Med	High	Med		Low	
Cucumbers	High	Low	Med			
Lettuce	High	Med	High	Med	High	
Oats	High	Low	High	Low	Low	Med
Onions	High	Low	High	High	High	
Parsnips	Med	Med	Med		Low	
Peas	High	Low	Low	Low	Med	
Peppers	Med	Low	Low		Med	
Potatoes	High	Low	Low	Med	Low	
Radishes	High	Med	Med	Med	Med	
Rye	Low	Low	Low	Low	Low	Low
Spinach	High	Med	High	High	High	High
Sugarbeets	High	Med	Med	Med	Med	High
Sweet corn	High	Med	Med	High	Low	Med
Tomatoes	Med	Med	High	Med	Med	High
Turnips	Med	High	Med		Med	

Mn = Manganese
B= Boron
Cu = Copper
Zn = Zinc
Mo = Molybdenum
Fe = Iron

[1] Taken, with permission, from the Michigan State University Cooperative Extension Publication E486 *Secondary and Micronutrients for Vegetables and Field Crop* (Table 3, Relative response of selected crops to micronutrient fertilizers).

Use caution when applying mixtures of several micronutrients, as crop injury may occur. Always follow the product label. Do not combine micronutrients with insecticide, fungicide or herbicide sprays unless there is information from the manufacturer of each product indicating that the mixtures are compatible. Many chelated micronutrients will consolidate in the spray tank if mixed with pesticides. Boron fertilizers will react with solupaks.

Use caution when applying micronutrients through fertigation systems. Certain micronutrient blends may cause the emitters to plug.

The use of micronutrients in the starter fertilizer is generally not recommended, as they often increase the amount of phytotoxicity, especially in adverse weather conditions.

Boron

Boron plays an important role in the structure of cell walls, fruit set and seed development. It is also a component of protein and carbohydrate metabolism.

Visual Symptoms

Boron deficiency symptoms vary widely between crops. In rutabaga and turnips, boron deficiency causes brown watery areas or hollow centres in the roots. Boron-deficient celery plants develop cracked stems, often with brown cat scratches and blackened hearts. In brassica crops, the deficiency appears as hollow stems and brown curds. Sugarbeets, table beets and spinach all develop yellow leaves with cracking on the roots.

Boron toxicity may occur when sensitive crops are planted in a rotation where boron has been applied (or over-applied). The toxicity symptoms include spot-like, striped or blotchy yellowing on the leaves. This leads to the death of the tissue, usually begining at the leaf tips and margins of older leaves. Under severe conditions, this will eventually develop over the whole plant.

Fertilizer Recommendations

There is no OMAFRA-accredited soil boron test. Some soil tests will report a soil boron value. Soil levels are often less than 1 ppm, making it very difficult to get an accurate measurement.

On request, fertilizer manufacturers may mix boron sources with ordinary fertilizers. **Do not band boron**. Foliar-applied sprays generally give faster and more effective results. Spray when the young plants are about 8 cm (3 in.) high. A second application may be required. See Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Management Notes

Some crops are very sensitive to boron, even at low levels. Consider the boron sensitivity of all rotational crops when applying boron. A soil pH between 5.0 and 7.0 provides the best conditions for boron uptake. Boron deficiencies are more likely to occur on soils with low organic matter, and on exposed or eroded subsoils. Boron availability decreases during periods of drought.

Copper

Copper is a component of chlorophyll production. It may also have a role in the suppression of some diseases.

Visual Symptoms

Copper deficiencies are most common in crops grown on organic (muck) soils. In carrots, it causes pale roots, while in onions it causes dieback and curling of the leaf tips. Copper-deficient onions may also have pale bulbs with thin scales. Copper-deficient lettuce leaves lose firmness and develop bleached yellow stems.

Fertilizer Recommendations

There is no OMAFRA-accredited soil copper test. Soil tests are unreliable on Ontario soils. Plant analysis is a more useful tool. If copper is required, see Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16. Use extreme care in applying copper sulphate to leaves, as phytotoxicity may occur.

Management Notes

Copper availability may be lower on coarse sands with very low organic matter and organic (muck) soils. Copper availability decreases as soil pH increases.

The addition of copper to muck soils helps slow the subsidence of the soil. When organic soils are first brought into cultivation, copper should be applied to the soil at 14 kg copper/ha (12.5 lb/acre) for each of the first 3 years. Subsequent applications of 5 kg copper/ha (4.5 lb/acre) should be made every second year thereafter.

Iron

Iron is needed for chlorophyll formation, plant respiration and the formation of some proteins.

Visual Symptoms

Iron deficiency first appears as yellowing between the veins of the newest growth. The veins will remain green except in extreme cases.

Fertilizer Recommendations

There is no OMAFRA-accredited soil iron test. An iron soil test does not correlate well with plant uptake or fertilizer response in Ontario. Plant analysis is a much more reliable indicator of iron availability.

Management Notes

Iron deficiencies are rare in Ontario. Factors associated with iron deficiency in other parts of the world are extreme imbalances with other metals such as molybdenum, copper or manganese. Excessive phosphorus in the soil may also contribute to iron problems. Soil with low organic matter or a combination of high pH, high lime and wet, cold soils can induce iron deficiency symptoms in sensitive crops.

Table 1–16.
Manganese Requirements

Manganese Index[1]	Manganese (Mn) Required[2] - kg/ha	
	Onions, Lettuce, Beets	Other Crops
0–7	2	0[3]
8–15	2	0
16–-0	0	0
50 + Above Normal	0	0

[1] Manganese Index = 498 + 0.248 (phosphoric acid extractable Mn in mg/L of soil) – 137 (soil pH) + 9.64 (soil pH)^2

[2] Manganese should be applied as foliar spray of manganese sulphate. Soil applications are inefficient.

[3] The manganese soil test is low, however manganese deficiency is not expected on this crop. If deficiency symptoms appear, make a foliar application of 2 kg Mn/ha in 200 L water (1.8 lb Mn/acre in 18 gal water.)

Manganese

Manganese is involved in photosynthesis and chlorophyll production. It helps activate enzymes involved in the distribution of growth regulators within the plant.

Visual Symptoms

Manganese deficiency causes yellowing between veins of young leaves. Leaves gradually turn pale-green with darker green next to the veins.

Manganese toxicity can occur on soils with a low pH. It causes brown spots or yellow, mottled areas near leaf tips and along the leaf margins. It usually develops on older leaves. Brown spots may also develop on veins, petioles and stems.

Fertilizer Recommendations

The OMAFRA-accredited manganese soil test uses a manganese availability index. This index evaluates manganese availability based on soil manganese level and soil pH. See Table 1–16, *Manganese Requirements*, above, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Management Notes

The manganese availability is greatest at a soil pH of 5.0 to 6.5. It is important not to add more lime than is needed to correct soil acidity. High organic matter levels decrease manganese availability.

Soil-applied manganese may be useful in acidic (low pH) sandy soils; however, on high pH and muck soils, foliar applications are often more effective than soil applications. If a manganese deficiency is confirmed, apply foliar sprays when the plants are about one-third grown or sooner. Two or more sprays may be necessary at 10-day intervals.

Molybdenum

Molybdenum plays an important role in nitrogen metabolism within the plant. It is involved with nitrogen fixation in legumes. It also plays a role in pollen viability and seed production.

Visual Symptoms

Early deficiency symptoms are similar to nitrogen or sulphur deficiency. Affected plants become stunted and lack vigour. Leaves may turn brown along the margins. Molybdenum deficiency causes cupping (whiptail) in cauliflower. Deficiency in legumes leads to poor nodule formation.

Fertilizer Recommendations

There is no OMAFRA-accredited soil molybdenum test. Deficiencies are best confirmed with a plant analysis. If molybdenum is required, see Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

See the individual commodity sections of Chapter 9 for recommended application methods and rates for brassica crops and onions.

Management Notes

Molybdenum availability improves with increasing soil pH. Liming can improve the availability on acid soils. Deficiencies may also occur under low soil moisture conditions.

Zinc

Zinc is important in early plant growth and in grain and seed formation. It also plays a role in chlorophyll and carbohydrate production.

Visual Symptoms

Zinc is relatively immobile within the plant. Deficiency symptoms appear first on younger leaves. Young leaves become mottled and show interveinal chlorosis, striping or banding. Susceptible plant symptoms are listed below.

Sweet corn

Pale yellow or white bands between the leaf margin and mid-vein in the lower part of younger leaves. Severely deficient plants have "white bud," where new leaves emerge from the whorl completely white.

Table 1–17.
Soil-Applied Zinc Requirements

Zinc Index[1]	Zinc (Zn) Required kg/ha: Corn, Onions	Zinc (Zn) Required kg/ha: Other Crops
0–7	4–14[2]	0[3]
8–14	4–14[2,3]	0
15–100	0	0
100 + Above Normal	0	0

[1] Zinc index reported = 203 + 4.5 (DTPA extractable soil zinc in mg/L of soil) – 50.7 (soil pH) + 3.33 (soil pH)^2

[2] The 14 kg Zn/ha rate should be sufficient for up to 3 years. Do not apply more than 4 kg Zn/ha as a banded application.

[3] The zinc soil test is low, however zinc deficiency is not expected on this crop. If zinc deficiency symptoms appear, make a foliar application.

Legumes

Thin, short stems, pale-green, bronzed foliage with yellow discolouration. Eventually the leaves turn a mottled yellow while the veins remain darker green.

Onions

Stunted growth with twisted, yellow-striped foliage.

Fertilizer Recommendations

The OMAFRA-accredited soil zinc test reports a zinc soil index value. This index evaluates zinc availability based on soil zinc level and soil pH.

Zinc deficiency can be prevented by the application of zinc fertilizer to the soil. See Table 1–17, *Soil-Applied Zinc Requirements*, above.

Early in the growing season, foliar sprays can be used to correct a deficiency after the symptoms have appeared. See Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16, for foliar zinc recommendations. Foliar applications of zinc are not recommended for sweet corn, as zinc is relatively immobile in the plant, and soil zinc is better able to supply the needs of the developing ears.

Management Notes

Zinc deficiencies are most often seen on sandy soils with high pH levels. Heavily eroded knolls may also have deficiency problems. Large applications of phosphorus may aggravate zinc deficiencies. Livestock manure is often an excellent source of zinc.

2. Soil Management

Vegetable production tends to be a very intensive process, usually involving a lot of tillage and numerous passes over a field. Most of the prime vegetable-growing soils are light in texture, and maintaining soil organic matter levels is a challenging and ongoing process. Soil organic matter contributes to soil structure, enhances soil moisture-holding capacity, increases the soil's ability to hold nutrients and improves drainage. Maintaining adequate soil organic matter levels will help support crop yields, particularly under adverse conditions.

Soil Quality

Soil quality is the measure of a soil's health and its ability to resist erosion, compaction and other stresses, while maintaining economic productivity. Many factors determine a soil's health. A healthy soil:

- has good soil structure and minimal compaction
- resists crusting
- has an abundance of earthworms
- smells good
- readily decomposes residue
- has good drainage, water movement and water-holding capacity
- encourages seedling emergence and root growth
- produces uniform crop growth and colour
- has optimal ranges of nutrient levels, pH and organic matter
- is resistant to wind, water or tillage erosion

The optimum soil organic matter level varies, depending on soil type.

Soil type	Optimum soil organic matter level
sandy	2%–4%
sandy-loam	3%–4%
loam	4%–5%
clay-loam	4%–5%
clay	4%–6%

Assessing the soil quality for each field and taking steps to maintain or improve it will ensure long-term productivity. Maintaining soil quality is a continuous process. Some measures are easy and relatively inexpensive to implement, while others require more effort and commitment to put in place. Table 2–1, *Maintaining or Improving Soil Quality*, on page 22, describes a variety of measures that can be used to help maintain or improve various aspects of soil quality.

For further information on soil management, see the OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices: Soil Management*, Order No. BMP06.

For more information on composting, see the OMAFRA Factsheet, *Agricultural Composting Basics*, Order No. 05-023.

Subsidence of Peat and Muck Soils

Cultivated peat and muck soils decompose or subside (oxidize) gradually at rates of 1–3 cm/year. Maintaining a high water table and a pH of 5.1–5.5 reduces the rate of subsidence to less than 0.05 cm/year. A very wet (or very acidic) soil does not give maximum yields and is likely to be flooded when rainfall is intense. Wet spots may also be difficult to work and may result in uneven crop growth. Keeping fields well drained during the growing season will ensure optimal crop growth. Raising the water table in the fall and winter will help reduce the rate of subsidence.

Research has shown that copper (Cu) applied as fertilizer has the residual effect of slowing down degradation (subsidence) by about 50%. Apply 14 kg of Cu/ha (12.5 lb/acre) annually to peats and mucks in the first 3 years of cultivation and up to 5 kg of Cu/ha (4.5 lb/acre) every second year thereafter, particularly when onions, carrots or lettuce are grown on the soils.

Table 2–1.
Maintaining or Improving Soil Quality

Measure	Comments
Easy/less expensive	
Use of cover crops	Use cover crops with fibrous root systems to improve soil structure, particularly in the seed bed. Use cover crops with tap roots to penetrate dense soil layers. Cover crops provide protection from erosion. Cover crops add active organic matter to support beneficial soil organisms.
Soil testing and accurate application of fertilizer and lime	Adequate pH and fertility will improve crop growth.
Reducing tillage and using residue management	Using fewer tillage passes to prepare the seedbed will: • leave more residue on the surface to protect against wind and water erosion. • reduce soil organic matter loss. • reduce crusting by leaving soil aggregates intact.
Adding organic matter in the form of manure or compost	Regularly adding organic materials to the soil will help increase organic matter levels in the soil, improve soil structure, increase the water-holding capacity and make the soil less prone to erosion. Manure is also a valuable source of nitrogen, phosphorous, potassium and many micronutrients.
Erosion control measures	Simple measures such as buffer strips, drop structures (rock chutes or drop pipes), tile outlet protection and strip cropping greatly reduce soil erosion. Structures such as water and sediment control basins help protect fields from major soil loss.
Significant management changes or investment required	
Minimum tillage	Switching to minimum or no-till systems will leave more residue on the surface and help protect the soil. It will also improve soil structure. It requires investment, equipment and management changes.
Crop rotation, including a mix of cereal, legume or grass crops	Rotating vegetable crops over a period of 2–4 years with cereals, legumes or forages will improve soil structure, improve the water-holding capacity and make the soil less prone to erosion.
Planting windbreaks	Treed windbreaks protect the soil and prevent sandblasting and desiccation of the crop. They may also provide the benefits of a microclimate. Results are seen in a few short years after planting, and the benefits can last a lifetime.
Planting windstrips	Established each year, grass wind strips can be adapted to many different crops. Similar to windbreaks, windstrips protect the soil and prevent sandblasting and desiccation of the crop and may provide microclimate benefits.
Improving drainage	Tile drainage will remove excess water, allowing for more timely field operations, reduced compaction potential and improved crop growth.

Tillage Systems

The traditional role for tillage has been to provide weed control and to prepare a seedbed that will give good crop stands and high yields. More recently, tillage and cropping systems have been changed to accomplish the same goals while reducing soil erosion through less intensive or no cultivation. Newer, more effective herbicides have reduced the need for aggressive mechanical weed control programs. Other factors favouring reduced tillage are savings on fuel and labour.

Base any decision to switch to a different tillage system on the system's compatibility with the farm's soil types, slopes, drainage, spring soil temperatures and the crop rotation. Tillage impacts erosion control as well as the timeliness of field work and the potential for controlling weeds, insects and diseases.

No one tillage system is best for Ontario conditions. Variability in soils, crops, climate and management mean tillage systems must be fine-tuned for each farm operation. In fact, the tillage system may rotate with the crop, allowing for the use of the most appropriate tillage for each crop.

Vegetable crops grown successfully in no-till and conservation tillage systems include:

- tomatoes
- sweet corn
- pumpkins
- squash
- brassica crops
- peppers
- snap beans

Conventional Tillage

Conventional tillage is any system that attempts to bury most of the previous crop residue, leaving less than 30% of the soil surface covered with residue after planting.

Usually, the moldboard plow is used in conjunction with a variety of other tillage implements.

The principal advantages of the moldboard system are that the machinery is familiar and widely available, and the system is adaptable to a wide range of soil conditions. Moldboard plowing increases soil porosity, allowing for air exchange, root proliferation and water infiltration, especially when rainfall is above average. However, the increased porosity can be lost with excessive secondary tillage, soil compaction or in soils with poor structural stability. Many livestock producers view the moldboard plow as the most effective tool for incorporating manure and breaking up sod fields.

The main weaknesses of the moldboard system include high costs of equipment, fuel and additional labour associated with seedbed preparation. With little or no residue cover, there is a high risk for soil erosion by wind and water. Adjusting the moldboards so that the soil is not completely inverted and some residue is left on the surface can help reduce some of these problems.

Conservation Tillage

Conservation tillage systems are designed to leave residue from the previous crop on the soil surface, providing more protection against erosion than conventional tillage. A variety of implements can be used for conservation tillage. The chisel plow has been the most widely adopted conservation tillage tool in Ontario. Tandem and offset discs are also used extensively in some areas of the province.

Fall chisel plowing with twisted shovel teeth will often leave ridges in the field the following spring. This can lead to extra costs in secondary tillage (more passes), uneven seed beds and occasionally excessive soil drying. Many of these problems can be overcome by:

- using sweep teeth on all or part of the chisel plow
- adding a levelling bar or harrows to the rear of the chisel plow
- practicing timely secondary tillage in the spring

Zone Tillage

Zone tillage (also known as strip tillage) combines the best of both no-till and conventional tillage systems. It uses both shanks and coulters to create a narrow (6–8 in. wide) zone of tilled soil that acts as a well-prepared seedbed. Each zone of tillage corresponds to the width of the planter units. The area between the rows is left undisturbed. This dramatically increases the amount of surface residue left on the field, while still creating the fine seed bed desired by many growers.

Zone tillage may be done in the fall, to aid in the timeliness of field work the following season, or in the spring, immediately before planting. This system has strong potential for crops such as sweet corn and pumpkins.

No-Till Systems

No-till systems provide the greatest opportunity to leave protective crop residues on the soil surface. They also have the greatest potential for reducing the cost of labour and fuel on the farm. One drawback of no-till is the increased reliance on "burndown" herbicides.

Numerous options exist, both in the original design and in the modifications available for row crop planters or seed drills to be considered capable of "no-till." Several Ontario equipment companies are leading the industry in the development of no-till vegetable planters.

No-till is a technique that can be used relatively easily with some vegetable crops. Maintaining surface crop or cover crop residues offers several benefits, including:

- the potential for weed suppression
- interference with the movement of some pests, e.g., Colorado potato beetle
- reduction of sand blasting and wind dessication
- reduction of soil water losses

However, concerns with insects and diseases, precision seeding and crop debris during machine harvest remain a challenge for many vegetable crops.

Tillage serves a slightly different purpose in organic vegetable production. Organic growers may rely heavily on timely cultivation to provide weed control. In certain organic crops, combining weed-suppressing cover crops with no-till practices may provide suitable weed suppression.

For further information on tillage systems, see the OMAFRA/Agriculture and Agri-Food Canada booklets:

- *Best Management Practices: Field Crop Production*, Order No. BMP02
- *Best Management Practices: No-Till: Making It Work*, Order No. BMP11
- *Best Management Practices: Soil Management*, Order No. BMP06

Table 2–2.
Selecting a Cover Crop

Function of the Cover Crop	Best Choice for Cover Crop
Nitrogen production	Red clover, peas or vetch
Nitrogen scavenging	Fall uptake – oilseed radish and other brassicas, oats Winter/spring uptake – rye, winter wheat
Weed suppression	Oilseed radish and other brassicas, winter rye Buckwheat
Nematode suppression[1]	Cutlass mustard Sudans/sorghums – Sordan 79, Trudan 8 Pearl millet – CFPM 101 Marigold – Crackerjack, Creole Oilseed radish – Adagio, Colonel
Soil structure building	Oats, overwintered winter rye
Compaction busting	Alfalfa, sweet clover
Biomass return to soil	Fall – oats, oilseed radish Summer – millets, sorghum, sudan
Erosion protection (wind or water)	Winter rye, winter wheat, ryegrass (well established)

[1] Nematode suppression is specific to the variety of cover crop and the species of nematode.

Cover Crops

Cover crops play a major role in soil management by providing ground cover to reduce erosion and by adding organic matter to improve or maintain the soil. Plant cover crops immediately after harvest to get the most benefit from the cover crop investment. While broadcast application and incorporation of cover crop seed works well to establish cover crops, direct seeding or drilling will ensure faster and more even establishment.

Knowing what you want to achieve with a cover crop will help you select the best one for the job. See Table 2–2, *Selecting a Cover Crop*, above, and Table 2–3, *Characteristics of Cover Crops Grown in Ontario*, on page 25. Cover crops can be divided into three groups based upon plant types: grasses, legumes and non-legume broadleaves.

Grasses

Grasses have fine, fibrous root systems that are well suited to holding soil in place and improving soil structure. Grass species suitable for cover crops are fast growing and relatively easy to kill (either chemically, mechanically or by winter temperatures). Grasses do not fix any nitrogen out of the atmosphere, but they can scavenge large quantities of residual nitrogen left in the field after harvest. Wind strips are usually created from overwintering grass cover crops.

Legumes

Legume cover crops can fix nitrogen from the air. They then supply it to the succeeding crop as well as protecting the soil from erosion and adding organic matter. The amount of nitrogen fixed varies between species. Generally, more top growth equals more nitrogen fixed. Ontario research has suggested that legume cover crops, such as red clover, are also effective at scavenging residual nitrogen from the soil.

Nitrogen release from legumes can be inconsistent. This must be accounted for when calculating your fertilizer needs. Excess nitrogen release late in the season could lead to excessive vegetative growth in fruiting vegetables, such as tomatoes, peppers and melons.

Some legume species, such as alfalfa or red clover, have aggressive tap roots that can break up subsoil compaction, but this requires more than one season's growth.

Non-Legume Broadleaves

These broadleaf crops cannot fix nitrogen out of the air but they may absorb large quantities from the soil. Growth will be poor if soil nitrogen levels are low or if compaction is severe. These crops are not winter-hardy, so additional control measures are not normally required. Do not allow these crops to go to seed, as the volunteer seed can become a significant weed problem.

Table 2–3.
Characteristics of Cover Crops Grown in Ontario

Species	Seeding Time	Seeding rate kg/ha	Nitrogen[1] Scavenging Potential	Overwintering Characteristics	Potential Weed Problem From Volunteer Seed	Nematode Rating [2]	
						Lesion	Root-knot
Grasses							
Ryegrass	April to May or Aug to early Sept	13–17	moderate	annual & Italian: partial survival Perennial: overwinters	no	—	—
Spring cereals – barley, oats	Mid-Aug to Sept	100–125	moderate	killed by heavy frost	no	+	—
Sorghum sudan	June to Aug	50	moderate-high	killed by frost	no	NH[2]	—
Pearl millet	June to Aug	9–10	moderate-high	killed by frost	no	NH[2]	NH[2]
Winter wheat	Sept to Oct	100–125	moderate-high	overwinters well	no	+	NH
Winter rye	Sept to Oct	100–125	high	overwinters very well	no	+[3]	NH
Legumes[4]							
Hairy vetch	Aug	20–30	low-moderate (fixes N)	overwinters	no	++	+
Red clover	Mar to April	8–10	low-moderate (fixes N)	overwinters	no	++	+++
Sweet clover	Mar to April	8–10	low-moderate (fixes N)	overwinters	no	—	—
Peas	July to Sept	50–100	low-moderate (fixes N)	killed by heavy frost	no	—	—
Non-Legume Broadleaves							
Buckwheat	June to Aug	50–60	moderate	killed by first frost	yes	+++	NH
Oilseed radish[5]	Mid-Aug to early-Sept	10–14	high	killed by heavy frost	yes	NH[2]	NH[2]
Mustards	Mid-Aug to early-Sept	3–5	high	Many killed by heavy frost but some may overwinter	yes	NH[2]	NH[2]

Nematode Rating Codes: — = poor or non-host + = ability to host NH = non-hosts

[1] The potential for nitrogen uptake is influenced by seeding date, stand establishment and growing conditions. Nitrogen-fixing legumes are less likely to take up residual nitrogen.

[2] Varietal differences in cover crop species may affect nematode reaction.

[3] Rye whole season rating would be higher (+++).

[4] Some diseases caused by *Pythium* and *Phytophthora* can be more severe after legume cover cropping.

[5] Oilseed radish residues can be toxic or allelopathic to subsequent crops if the following crop is planted too closely after green manuring. Allow the green manure residues to break down or dessicate before planting the next crop.

For more detailed information on cover crop use and management, see the OMAFRA website at ontario.ca/crops.

Tillage Systems After Cover Crops

In conservation and no-till cropping systems, cover crops can greatly increase the surface residue cover, adding to the potential benefits of the system.

Here are some management factors to consider when reduced tillage follows cover crops:

- Some regrowth of winter annual, biennial or perennial cover crops will occur in the following crop year. Usually this is easily controlled with normal herbicide treatments in the following crop. A controlled amount of regrowth (e.g., windstrips) can provide some spring wind protection.
- The first conservation tillage operation with overwintering cover crops should occur at least 2 weeks prior to planting the main crop to allow for the breakdown of the residue to start.
- Seedbed preparation may be difficult if persistent cover crops are not tilled until spring or if they are allowed to grow too large.
- Cover crops that do not survive over winter may be an option, especially on more poorly drained soils or for crops that are planted very early in the spring.
- Burndown herbicides should be considered before conservation tillage of overwintering cover crops such as rye. Careful timing, rate and application of herbicides can help keep enough residue on the surface to prevent wind damage to tender crops while allowing crop establishment.

3. Water Management

Water is a valuable resource. A clean and abundant supply of water is critical to the success of the farm business and the health of your family. Farm operations impact water quality in many ways. Soil erosion, manure, septic system effluent, fertilizers, pesticides and fuel can affect surface and/or groundwater quality. On a positive note, farm woodlots, fence rows and buffer strips surrounding creeks and streams all add to the natural diversity of the Ontario landscape.

Improving Water Quality

The greatest water quality challenges involve bacteria, nitrates and soil erosion. Problems can be minimized using the following practices.

Bacterial Contamination

- Contain runoff from cull piles, manure storages, livestock yards and silos.
- Avoid spreading manure on frozen or snow-covered ground.
- Make sure well heads and casings are properly maintained and protected from surface contamination.
- Ensure that the domestic septic system is working properly and is not discharging.

Soil Erosion

- Where possible, adopt the conservation tillage practices outlined in Chapter 2, *Soil Management*, on page 21.
- Install erosion-control structures.
- Use cover crops and wind-abatement crops.
- Maintain buffer strips surrounding creeks, streams and ponds to act as natural filters of sediment and soil-borne contaminants.

Nitrate Contamination

- Avoid spreading excessive amounts of manure or fertilizers.
- Use cover crops to capture residual nitrogen.
- Consider using the soil nitrate test to help determine nitrogen requirements.
- Reduce nitrogen fertilizer when the previous crop was a legume or when manure was applied.

For more information on protecting water quality, see:

- OMAFRA Factsheet, *Protecting the Quality of Groundwater Supplies*, Order No. 06-115
- OMAFRA Factsheet, *Environmental Impacts of Nitrogen Use in Agriculture*, Order No. 05-073
- OMAFRA Factsheet, *The Planning and Maintenance of an Erosion Control System*, Order No. 97-015
- OMAFRA Factsheet, *The Use of Earthen Berms for Erosion Control*, Order No. 99-047
- *Best Management Practices: Water Management*, Order No. BMP07
- *Best Management Practices: Pesticide Storage, Handling & Application*, Order No. BMP13
- *Best Management Practices: Water Wells*, Order No. BMP12
- *Best Management Practices: Fish and Wildlife Habitat*, Order No. BMP10
- *Best Management Practices: Buffer Strips*, Order No. BMP15

Irrigation

Most vegetable crops require a uniform supply of moisture throughout the growing season. The average rainfall in Ontario is 70 mm (3 in.)/month during the growing season. For most vegetable crops, this provides only 65% of the water needed for optimum yield. Historically, moisture levels are often at their lowest in July and August when the crop water demand is at its highest.

Common defects caused by moisture stress in vegetable crops include:

- blossom end rot
- growth cracks
- hollow heart
- fruit deformities
- tipburn
- poor seed/kernel development

Note: You must have a Permit to Take Water issued by the Ministry of the Environment to use more than 50,000 L of water in a day from either surface or groundwater sources.

Table 3–1. Vegetable Crop Rooting Depth

Shallow-Rooted (down to 30 cm)	Intermediate (30–60 cm depth)	Deep-Rooted (deeper than 60 cm)
broccoli	beans, snap	asparagus
cabbages	carrots	parsnips
cauliflower	muskmelons	pumpkins
celery	peppers	sweet corn
cucumbers	tomatoes	watermelons
lettuce	zucchini	winter squash
onions		
potatoes		
radishes		

Crops and Water Demand

Soil types differ in their ability to retain water following rainfall or irrigation. Water that is held by the soil and can be taken up by plants is called "available soil water" (ASW). The irrigation point for overhead irrigation systems occurs when the ASW drops below 40%–60%, depending on the crop's rooting depth. The trigger for drip irrigation systems is usually 85%. When the soil moisture drops below this point, crop yield and quality may be affected. The frequency of irrigation will depend on weather, crop rooting depth, crop growth stage, soil texture and the type of irrigation used.

Crop Rooting Depths

Different vegetable crops also vary in their response to irrigation. Shallow-rooted crops such as potatoes and celery require frequent, light irrigations. These crops will often respond to overhead irrigation when the ASW reaches 60%. Deep-rooted crops can use water from a greater volume of the soil profile and do not require irrigation as frequently. For these crops, overhead irrigation may often be delayed until the ASW reaches 40%–50%. Table 3–1, *Vegetable Crop Rooting Depth*, above, shows the relative rooting depths of a number of vegetable crops.

Critical Growth Stages

Most vegetable crops have growth stages during which drought stress can severely reduce yield and quality. Irrigation is especially important during these critical growth periods, which are listed in Table 3–2, *Critical Periods for Irrigation of Several Vegetable Crops*, above.

Soil Water-Holding Capacity

The different soil types vary in their ability to hold water. As seen in Table 3–3, *Average Available Soil Water Capacity*, right, the coarse sands and loamy sands hold considerably less water than the silt loams and silty clay loams. Soils with a low water-holding capacity often require weekly replenishment. Heavy applications may be a waste as these soils are not able to hold more than 25–33 mm (1–1.25 in.) of water at any given time.

Table 3–2. Critical Periods for Irrigation of Several Vegetable Crops

Critical Period	Crop
Flowering, pod setting	snap beans
Head formation and enlargement	broccoli cabbages cauliflower
Tasselling, pollination, ear filling	sweet corn
Bulb formation and enlargement	onions
Flowering, fruit set and enlargement	cucumbers muskmelons watermelons zucchini eggplant peppers tomatoes

Sandy loam and silt loam soils retain considerably more soil water. On these soils, it is possible to schedule heavier and less frequent irrigation events.

For an indication of the maximum amount of water available for the crop, multiply the average water capacity from Table 3-3 by the rooting depth found in Table 3-1. For example, the maximum amount of water available for a carrot crop grown on a sandy loam soil would be 66 mm (2.5 in.). In this example, an irrigation application should be made once the crop's ASW has fallen below 50% (33 mm or 1.25 in.).

Table 3–3. Average Available Soil Water Capacity

Soil Texture	mm of water per mm of soil (equivalent to inch of water per inch of soil)
Sands	0.065
Loamy sand	0.085
Sandy loam	0.11
Loam	0.15
Silt loam	0.16
Silty clay loam	0.18
Clay loam	0.17
Clay	0.16

Table 3–4.
Average Intake Rate for Soil Textures

Soil Type	in./hr	mm/hr
Sands	0.70	12–25
Loamy sand Sandy loam Loam	0.55	7–20
Silt loam Silty clay loam Clay loam	0.25	4–8
Clay	0.20	2–6

During the hot part of the growing season, irrigation applications should be more frequent. Likewise, during the cool part of the growing season, irrigation applications are required less often.

Application of unnecessarily high amounts of irrigation wastes water and can cause leaching of fertilizers and pesticides. Water must be applied slowly to avoid runoff. The water application rate must not exceed the average intake rate for each soil type. See Table 3–4, *Average Intake Rate for Soil Textures*, above.

Irrigation Systems

A number of different types of irrigation systems have been adapted for use in vegetable crops. They include hand-moved sprinklers, travelling gun systems, centre-pivot and lateral systems, and drip (trickle) irrigation.

A more detailed description of each of these systems can be found in *Best Management Practices: Irrigation Management*, Order No. BMP08.

Irrigation Scheduling

Whichever type of irrigation system is used, it is important to use some method of irrigation scheduling to avoid drought stress and provide water when it is most needed. Timely application of water will reduce the potential for nutrient loss or disease pressure due to excess water. There are two basic methods of irrigation scheduling: the water budget method and measuring soil moisture.

Water Budget Method

This method uses climatic data to estimate the amount of available water lost from the rooting zone through crop use and evaporation. The amount of crop water use is calculated using the percentage of crop cover and the evapotranspiration (ET) rate from climatic data. Average daily ET rates from May through September are listed for several locations across Ontario in the *Irrigation Best Management Practices Booklet*. Actual ET rates may be obtained from Weather INnovations Incorporated at www.weatherinnovations.com.

Measuring Soil Moisture

There are several tools available for measuring soil moisture content.

Tensiometers measure how strongly water is held by the soil. As the soil dries out, moisture is more strongly held to soil particles and less available to the crop. Tensiometers can be used to determine when moisture stress occurs, and thus when irrigation should be started. Irrigate sandy soils when soil moisture tension reaches 15–20 centibars. Irrigate loamy soils at 20–25 centibars. These units require proper installation and regular maintenance. Accuracy may be reduced on soils with high clay content.

Electrical resistance blocks also measure soil water tension in centibars. Compared to tensiometers, they are easier to install. The portable meter and low cost of the units is more conducive to reading soil moisture at several different sites.

Time domain reflectometry (TDR) is a more costly tool for soil water monitoring. It is portable and quick. These units measure volumetric water content (%VWC). Some units require calibration. Accuracy may be reduced on soils with high clay content. These units will normally last many seasons, although the steel probes do have a tendency to bend if not handled carefully. Damaged probes may affect the accuracy of the TDR.

Capacitance sensors (C-probe, EnviroSmart, EasyAg, Profile Probe, etc.) measure the volumetric water content of the soil (mm water/mm soil). Until recently, this technology was used primarily in research trials. Due to decreasing per unit costs, capacitance-based probes are becoming more available for on-farm use.

Capacitance sensors are housed in a waterproof access tube. Multiple sensor points may be fixed along the length of the tube to give readings at different soil depths representative of the crop's rooting zone. The tube is installed at a fixed location in the field, and daily readings are recorded by a data logger or through remote telemetry. A graph is created for each location, allowing the grower to quickly assess water needs. Selecting an appropriate location for the probe is critical to ensuring the information gathered is representative of the entire field.

For more irrigation information, see:

- *Best Management Practices: Irrigation Management,* Order No. BMP08
- OMAFRA Factsheet, *How to Prepare for Irrigation During Water Shortages,* Order No. 99-023
- OMAFRA Factsheet, *Irrigation Scheduling for Tomatoes – Water Budget Approach,* Order No. 90-049

Fertigation

Fertigation is a method of applying water and nutrients through a drip irrigation system. It can be used to increase the yield and quality of many vegetable crops.

Dissolve a stock solution of soluble fertilizer in a tank and introduce it through a valve into the irrigation system either by suction or pressure. Feed the fertilizer solution through the system slowly. After the fertilizer has passed through the system, continue to irrigate to flush the lines. **Do not apply phosphorus through the drip tape.**

Fertigation applications are usually made weekly. However, depending on the design of the irrigation system, the soil type and time constraints, applications may be made more-or-less frequently. It is important that the irrigation cycle is run for ample time to adequately flush the system after each fertigation event.

For more information on fertigation, see the sections on fertigation on pages 10 and 14, as well as the individual commodity sections of Chapter 9, starting on page 67.

4. Climate and Season Extension

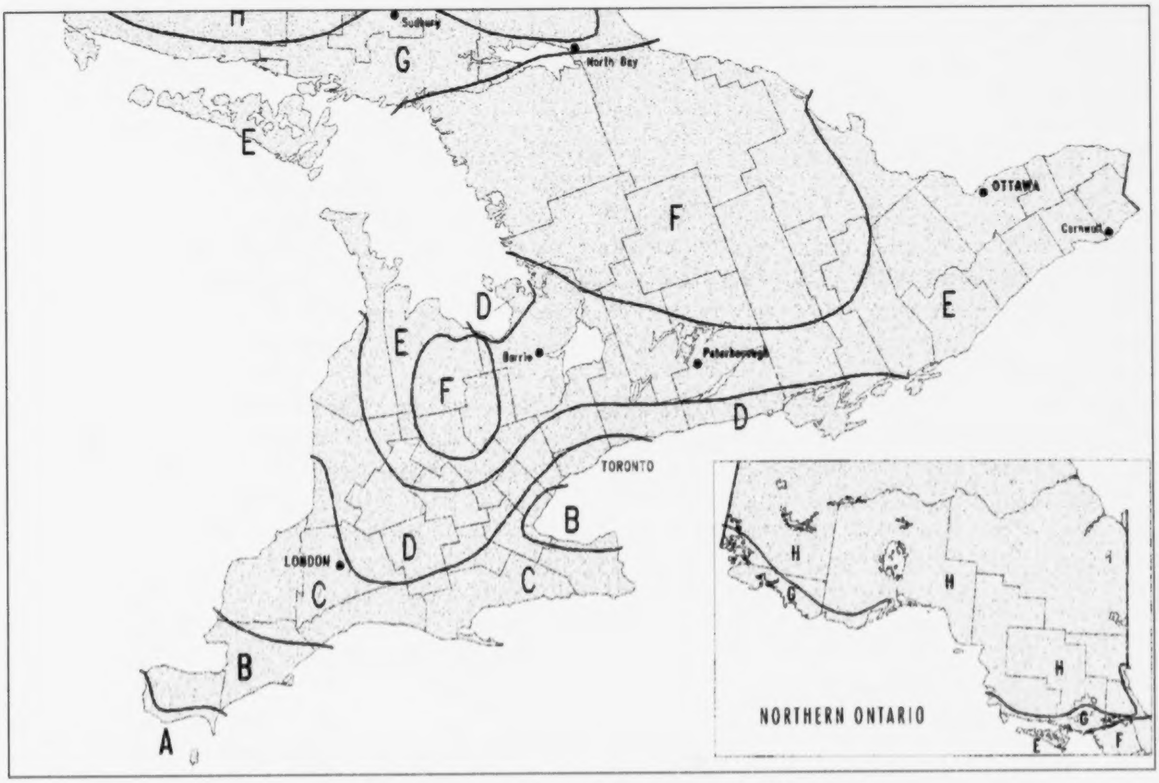

Figure 4–1. Climate Zone Map of Ontario (1961–90)

Climate

Most vegetable production is concentrated in Southern Ontario. There are differences in climate even in this small area. The length of the growing season and average temperatures can vary greatly from one area to the next. Vegetable crop development is usually referred to by the number of "days to maturity." This measure indicates the average number of calendar days from planting to harvest maturity. However, due to variability in daily temperatures and light intensity, this measure of "days to maturity" does not always reflect the rate of crop growth under actual growing conditions.

Climate Zones

Figure 4–1, *Climate Zone Map of Ontario (1961–90)* above, shows the Ontario climatic zones. Table 4-1, *Average Frost-Free Period in Climatic Zones of Ontario*, right, gives the average dates of first and last frost (0°C or 32°F) in each zone, based on climate data from 1961 to 1990.

Table 4–1.
Average Frost-Free Period
in Climatic Zones of Ontario (1961–90)

Zone	Frost-Free Period (Average in Days)	Average Date of Last Spring Frost	Average Date of First Fall Frost
A	180	April 25	October 25
B	165–180	May 5	October 15
C	145–165	May 10	October 10
D	130–145	May 18	October 2
E	120–135	May 22	September 28
F	105–120	May 31	September 20
G	100–120	May 25	September 15
H	100 or less	after May 25	before Sept. 15

Zone A, in the Leamington-Harrow-Amherstburg area bordering on Lake Erie, has the longest growing season. The growing seasons of the other zones are progressively shorter. The zone lines on the map are approximate and

Table 4–2.
First Field Seeding or Planting Dates for Commercial Production

Crops	Zone A	Zone C	Zone E
Frost Hardy			
Asparagus, broccoli, Brussels sprouts, cabbages, lettuce, onions (set, seed, Spanish), radishes, rhubarb, peas, spinach, parsnips, early potatoes	April 1–15	April 15–25	April 25–May10
Semi-Frost Hardy			
Beets, carrots, cauliflower, celery, late potatoes, early sweet corn	April 15–25	April 25–May 10	May 5–15
Semi-Frost Tender			
Snap beans, sweet corn, tomatoes	May 1–15	May 15–25	May 25–June 5
Frost Tender			
Lima beans, cucumbers, eggplant, muskmelons, peppers, pumpkins, squash, watermelons	May 20–30	May 25–June 5	June 5–15

do not represent sharp changes in climate. The changes in temperature and growing season from one zone to another are gradual.

The dates listed in Table 4–1 indicate that 50% of the time (one year in two) there will be no frost in these locations after that date. There is a 25% risk of a frost occurring 7 days after the listed last spring frost date. Fourteen days after the listed date, the risk decreases to 10%. Conversely, there is a similar risk factor associated with frost occurring before the first fall frost dates.

Note that the frost dates in Table 4-1 refer to the occurrences of 0°C (32°F) at a standard height of 1.5 m, at which time tender crops will often be damaged. Frost-hardier crops are not usually damaged until temperatures at this height drop below –2°C (28°F). The date of occurrence of –2°C (28°F) is usually about 2 weeks earlier in the spring or later in the fall than the dates mentioned in the table. For a list of vegetable crops and their comparative hardiness, see Table 4–2, *First Field Seeding or Planting Dates for Commercial Production*, above.

Growing conditions are also influenced by local variations in topography, altitude, natural air drainage and nearness to water. Cold air tends to flow into low-lying areas. Plants at the bottom of a slope are often the first to suffer frost injury. Local variations must be considered in deciding the location and time of planting.

For more information on recommended planting dates and conditions, see Chapter 5, *Seeding and Transplanting*, on page 37.

Temperature Models

Growing Degree Days

Growing degree days (GDDs) are used to estimate the growth, development and maturity of plants and insects during the production season. They tend to be more accurate than "days to maturity."

The development of most crops and insects is closely related to the daily accumulation of heat. A certain amount of heat is required to provide enough energy for a plant or insect to move to its next development stage. For example, it takes 300 GDDs for the first emergence of European corn borer moths to occur in Southwestern Ontario. The GDD heat requirements do not change from year to year. But, depending on weather conditions, the amount of actual time (calendar days) can vary between years.

Each species of plant and insect has a minimum base temperature or threshold at which development does not occur. These base temperatures are different for each organism.

To calculate GDD, first determine the mean daily temperature. This is done by taking the maximum and minimum temperatures for the day, adding them together and dividing by two. The base temperature is then subtracted from the mean temperature to give a daily GDD. If the resultant daily GDD is a negative number, count it as zero. Each daily GDD is then added up (accumulated) over the growing season.

$$\frac{\text{Daily Maximum Temperature} + \text{Daily Minimum Temperature}}{2} - \text{Base} = \text{Growing Degree Days}$$

There are GDD models developed for most vegetable crops and several insect pests. See Table 4–3, *Insect Growing Degree Days Base Temperatures*, and Table 4–4, *Vegetable Growing Degree Days Base Temperatures*, on page 33, for examples of specific GDD base temperatures.

Table 4–3.
Insect Growing Degree Days Base Temperatures

Insect	GDD Base Temp (°C)
Aster leafhopper	9
Cabbage maggot	6
Carrot rust fly	3
Carrot weevil	7
Corn borer	10
Cutworms	7
General insects	15
Onion maggot	4
Tarnished plant bug	9

There are four factors to consider when comparing GDD accumulations from various sources or regions.

- **Are the base temperatures used in the equations the same?** Different organisms have different base temperatures used to calculate growing degree days. 150 GDDs at base 10 does not equal 150 GDDs at base 0.
- **Are the start dates for the accumulations the same?** Generally, GDD accumulations start on April 1 each year, but some insect GDD models start at the emergence of a specific life stage. This is referred to as a biofix.
- **Are the equations used to calculate the daily GDDs the same?** Many modifications to the simple GDD calculation have been developed over the years and may still be referred to as degree days.
- **Are the temperatures used in degrees Celsius or Fahrenheit?** GDD accumulations will vary significantly, depending whether they are being tracked in Celsius or Fahrenheit. GDD models have been designed specifically for use in Celsius or in Fahrenheit and cannot be interchanged without making conversions.

Confusion has been created over the years by the terminology used to describe growing degree days. In Ontario, the terms "growing degree days" (GDDs) and "crop heat units" (CHUs) represent two very different development models. The crop heat units calculation used in Ontario is identical to the traditional corn heat units calculation. Its name was changed to reflect its now broader application to other crops.

Table 4–4.
Vegetable Growing Degree Days Base Temperatures

Base Temperature (C°)					
2.2	**4.4**	**7**	**10**	**13**	**15.5**
spinach	asparagus beet broccoli carrot lettuce pea potato	squash	bean (snap) cantaloupe pepper sweet corn tomato	cucumber watermelon	eggplant sweet potato

Growing degree days are sometimes referred to as "degree days" or "degree days averaging method." Some jurisdictions use the term "heat units" interchangeably with degree days.

Crop Heat Units (CHUs)

While the principles are similar, the equation for a CHU is more complicated than the equation for a GDD. Crop heat units place limits on maximum and minimum temperatures. Like the base temperature used in GDDs, the limits used in CHUs are determined experimentally and are specific to the crop concerned.

$$\text{Daily CHU} = (Y_{max} + Y_{min}) \div 2$$

$$Y_{max} = [3.33 \times (T_{max} - 10)] - [0.084 \times (T_{max} - 10)^2]$$

$$Y_{min} = [1.8 \times (T_{min} - 4.4)]$$

- If values are negative, set to 0.
- Tmax and Tmin = Daily maximum or minimum air temperature in degrees Celsius, usually measured from midnight to midnight.

The calculations for daily minimum and daily maximum temperatures account for important factors in the growth of warm-season crops. Warm-season crops such as corn do not grow in temperatures below 10°C (50°F). Corn and other warm-season crops grow faster as the temperature increases up to 30°C (86°F). Above 30°C (86°F), growth of even warm-season crops slows.

For more information on crop heat units, see the OMAFRA Factsheet, *Crop Heat Units for Corn and Other Warm-Season Crops in Ontario*, Order No. 93-119.

Table 4–5.
Plastic Mulch Types

Type	Average Soil Warming at 2 in. depth	Advantages	Disadvantages
Black	2°C–4°C	Prevents weed seed germination.	Good soil-to-plastic contact is necessary to ensure maximum heat transfer.
Clear	4°C–8°C	Can be used with direct-seeded crops such as sweet corn.	Weed germination under the mulch requires good preplant (residual) weed control.
White	−1°C (cools the soil)	Keeps the soil temperature lower to minimize bolting in cool season crops.	Weed germination may occur under the mulch. Requires good preplant weed control.
Infra-red transmitting (IRT)	6°C	Absorbs certain wavelengths of light, preventing weed seed germination and growth.	Expensive. Tomato and pepper yields may be lower on IRT mulches than on black.
Photo-degradable	Same as undegradable mulch	Breaks down with exposure to sunlight, eliminating the need for retrieval and disposal at the end of the season.	Rate of breakdown can be inconsistent. Buried edges frequently do not break down, leaving plastic residue in the field. These plastic residues are often difficult to retrieve.
Biodegradable	Same as undegradable mulch	Usually a starch-based plastic. Broken down by soil micro-organisims.	Most of these mulches are relatively new in the marketplace, and only limited quantities are available. There is a big range in the quality and degradability of products. Always field-test new products on a limited scale first.

Season Extension

Many vegetable crops, especially heat-loving crops such as cucurbits (vine crops), peppers, tomatoes, eggplant and sweet corn, benefit from the use of plastic mulch and row covers. Some benefits associated with season extension include:

- earlier harvest
- increased yield
- higher-quality produce
- soil moisture retention
- reduced disease pressure
- reduced fertilizer leaching
- increased season-long nutrient availability
- weed control

Plastic Mulch

Most mulches are made of polyethylene. Table 4–5, *Plastic Mulch Types*, above, describes the different types. They are available in widths of 1.2–1.5 m (4–5 ft) with a thickness of 1–1.5 mil (thousandths of an inch).

Several commercial plastic mulch layers are available. Proper set-up of the mulch layer is essential. The edges of the mulch should be well covered, and the plastic should be tight on the soil surface to permit heat transfer to the soil. Angle the discs and press wheels of the mulch layer to ensure a tight and uniform fit.

Do not lay mulch on dry soil. If the soil is very dry, irrigate or wait for rainfall before laying. Soil moisture is important for heat retention. Lay mulch 2–3 weeks prior to planting for maximum soil heating.

Row Covers

Row covers can be used to promote earlier production by increasing the canopy air temperature and protecting young transplants from wind damage. There are two basic types: floating row covers and low tunnels.

Regardless of the type of row cover used, heat can build up inside the covers and damage crops. Temperatures should be monitored. Remove or ventilate the covers when the temperature exceeds 32°C–35°C (90°F–95°F). For crops that require bee pollination (vine crops), row covers must be removed or opened up at flowering time.

High temperatures under the row cover during flowering may cause fruit deformities or a decrease in pollen viability.

Floating Covers

These are made of polypropylene or various polyester-type fabrics and are laid directly over the crop. They are available in sheets up to 15 m (50 ft) wide to cover multiple rows. Floating covers are well suited for large acreages and low-growing plants. They are not recommended for use on upright-growing crops such as tomatoes and peppers. They may cause abrasions on the plant's shoot tips.

Low Tunnels

These are made of white or clear polyethylene and are supported over the crop on wire hoops. The plastic usually has slits or perforations for ventilation. Commercially available layers install hoops, lay the plastic covers over the hoops and bury the edges of the row cover in one operation.

Research in Ontario has demonstrated that use of low tunnels can result in earlier production of lettuce, peppers, cucumbers and melons. Tunnels used on fresh-market tomatoes should be removed well before flowering. Extended use of row covers on tomatoes may result in reduced fruit set.

High Tunnels

A high tunnel is a semi-permanent, simplified greenhouse. It is typically made of a metal tubing framework and a single sheet of polyethylene plastic. Each end of the tunnel is open or contains a large wooden door frame, allowing for the use of small field equipment inside the tunnel.

A high tunnel may expand the growing season by 3–4 weeks, but will not function well for growing during the winter. It is possible to expand the growing season even more by adding temporary heaters to the structure.

In addition to expanding the growing season, high tunnels may improve the harvest quality of certain vegetable crops. Shoulder-checking (russetting) and cracking of tomatoes may be reduced when the fruit is protected from rain. A reduction in leaf wetness may also help reduce disease problems.

During the hot summer months, the tunnels may be ventilated simply by rolling up the plastic sidewalls, allowing air to move through the structure. As the inside of the tunnels does not receive any natural rainwater, drip irrigation is highly recommended.

Remove the plastic from the high tunnel during the winter months. This will improve the lifespan of the plastic. It will also prevent structural damage to the tunnel due to snow load or inclement weather.

Plastic Disposal

Used plastic mulches are difficult to recycle due to the amount of dirt, plant material and water present. Limited recycling opportunities do exist in some areas. In most areas, disposal at a licensed landfill site is currently the most practical option. Burning or on-farm burial is not recommended.

5. Seeding and Transplanting

Plant Populations

Each crop should be spaced according to its optimum needs. The distance between rows will also be determined by the method used to harvest the crop. Specific spacing recommendations can be found for each individual commodity in Chapter 9, starting on page 67.

For average plant populations at various row spacings, see Table 5–1, *Plant Populations at Various Planting Distances*, below.

Table 5–2, *Row Length per Acre or per Hectare at Various Row Spacings*, on page 38, shows the row length per acre (or hectare) at various row spacings.

Table 5–1.
Plant Populations at Various Planting Distances

	per acre									
Row Spacing (in.)	Distance within the Row (in)									
	4	6	12	18	24	30	36	48	60	96
12	132,000	87,120	43,560							
18	88,000	58,080	29,040	19,360						
24	66,000	43,560	21,780	14,520	10,890					
30	52,324	34,848	17,424	11,616	8,712	6,969				
36	43,560	29,040	14,520	9,680	7,260	5,808	4,840			
44	39,600	23,803	12,100	8,066	6,050	4,840	4,033	3,025		
48	33,507	21,780	10,890	7,260	5,445	4,356	3,630	2,722		
60			8,712	5,808	4,356	3,484	2,904	2,178	1,742	
96			5,445	3,630	2,722	2,178	1,815	1,361	1,089	680
120					2,178	1,742	1,452	1,089	871	544

	per hectare									
Row Spacing (cm)	Distance within the Row (cm)									
	10	15	30	45	60	75	90	120	150	240
30	326,040	251,186	107,593							
45	217,360	143,457	71,728	47,819						
60	163,020	107,593	53,796	35,864	26,898					
75	129,240	86,074	43,037	28,691	21,518	17,213				
90	107,593	71,728	35,864	23,909	17,932	14,345	11,954			
110	97,812	58,793	29,887	19,923	14,943	11,954	9,961	7,471		
120	82,762	53,796	26,898	17,932	13,449	10,759	8,966	6,723		
150			21,518	14,345	10,759	8,605	7,172	5,379	4,302	
240			13,449	8,966	6,723	5,379	4,483	3,361	2,689	1,679
300					5,379	4,302	3,586	2,689	2,151	1,343

Table 5–2. Row Length per Acre or per Hectare at Various Row Spacings

Distance Between Rows		Length of Row	
Imperial	Metric	Feet of Row/ Acre	Metres of Row/ Hectare
6 in.	15.24 cm	87,120	65,606
12 in.	30.48 cm	43,560	32,802
18 in.	45.72 cm	29,040	21,868
20 in.	50.80 cm	26,136	19,682
24 in.	61.96 cm	21,780	16,401
30 in.	76.20 cm	17,424	13,121
36 in.	91.44 cm	14,520	10,934
40 in.	1.016 m	13,068	9,840
42 in.	1.067 m	12,445	9,372
48 in.	1.219 m	10,890	8,200
60 in.	1.524 m	8,712	6,561
72 in.	1.829 m	7,260	5,467
84 in.	2.134 m	6,223	4,686
96 in.	2.438 m	5,445	4,100
108 in.	2.743 m	4,840	3,645
120 in.	3.048 m	4,356	3,280

Seeding

Use only high-quality seed that is certified disease-free. In most vegetable crops, seed treatments are recommended to protect against early-season insects and diseases. Registered seed treatments are listed in the individual crop sections in Chapter 9, *Crop Management Recommendations*, starting on page 67.

Saving your own seed is not recommended. Saved seed has a high potential for disease contamination, and seed harvested from hybrid cultivars will not grow true to type. Common vegetable diseases that may be transmitted by infected seed include late blight in potatoes, as well as gummy stem blight and angular leaf spot in vine crops. Many of the viruses infecting vegetables are also seed borne.

Pelletized seed has been coated to make it larger or more uniform. Onion, carrot and lettuce seed tends to be irregularly shaped or small. Pelletized seed makes the mechanical planting of these crops much easier.

Primed seed has been partially hydrated, then dried down. This treatment results in earlier germination and better uniformity, especially for hard-to-germinate seeds.

Table 5–3. Minimum Soil Temperatures for Vegetable Seed Germination

Vegetable	°F	°C	Vegetable	°F	°C
Asparagus	50	10	Okra	60	16
Bean	60	16	Onion	35	2
Bean, lima	60	16	Parsley	40	4
Beet	40	4	Parsnip	35	2
Cabbage	40	4	Pea	40	4
Carrot	40	4	Pepper	60	16
Cauliflower	40	4	Pumpkin	60	16
Celery	40	4	Radish	40	4
Chard, Swiss	40	4	Spinach	35	2
Corn	50	10	Squash	60	16
Cucumber	60	16	Tomato	50	10
Eggplant	60	16	Turnip	40	4
Lettuce	35	2	Watermelon	60	16
Muskmelon	60	16			

Soil Temperature

Soil temperature has an enormous impact on the early-season growth and development of a crop. Seeds planted into cold soils may be damaged by low temperatures. This can delay or even inhibit germination and stand establishment, reducing a field's yield potential. Acceptable soil temperatures vary greatly between the different vegetable crops. See Table 5–3, *Minimum Soil Temperatures for Vegetable Seed Germination*, above.

Planting Depth

Achieving the appropriate planting depth is a critical component of crop establishment and early-season growth. Improper seed placement often results in a reduced stand establishment and lower yields. Seeds planted too close to the surface may not receive enough soil moisture to germinate and often fall prey to seed predators. Seeds planted unnecessarily deep will be slow to emerge, especially in cold soils. Slow-emerging plants are more susceptible to seed decay or seed insects, such as the wireworm or seed corn maggot. Table 5–4, *Field Seeding Depth and Seeds per Gram*, on page 39, outlines the approximate planting depth and number of seeds per gram for each vegetable crop.

Table 5–4.
Field Seeding Depth[1] and Seeds per Gram

Crop	Seeds (per gm)	Planting Depth (mm)	(in.)
Asparagus	50	25	1
Beans, snap	2–3	40	1⅔
Beans, lima	1–3	40	1⅔
Beets, Swiss chard	50	15	½
Brassica crops – seeded	280–350	5	¼
Brassica crops – transplants	280–350	–	3–4
Carrots	900	5	¼
Celery, celeriac	1,800	3	⅛
Chicory	600	5	¼
Collard	280	5	¼
Corn	4–8	25–65	1–2½
Cucumbers	40	20	¼
Eggplant – transplant	200		3–4
Endive	500	5	¼
Kale	270	5	¼
Kohlrabi	280	5	¼
Leeks	350	15	½
Lettuce	700	5	¼
Melons	40	25	1
Mustard – transplant	550		3–4
Onions	280	15	½
Parsley	550	5	¼
Parsnips	200	15	½
Peas	3–6	25	1
Peppers – transplant	150		3–4
Pumpkins – seeded	4	25	1
Pumpkins – transplant	4	–	3–4
Radishes	125	15	½
Rutabagas	280	5	¼
Spinach	90	20	¾
Squash – seeded	10	25	1
Squash – transplant	10	–	3–4
Tomatoes – transplant	350		3–4
Watermelons – transplant	10		3–4

[1] The planting depths listed here are for field placement. See Table 5–8, *Vegetable Transplant Requirements*, on page 41, for transplant production recommendations.

Seed Storage

Germination and vigour of all seed declines over time. Seed storage temperatures of 5°C–10°C (40°F–50°F) and 40%–50% relative humidity are ideal. Excessively low humidity may result in poor germination rates. High humidity will increase the likelihood of fungal contamination.

Seed should be stored in waterproof, vapourproof containers. Life expectancy, even under good storage conditions, varies between different types of vegetable seed. See Table 5–5, *Vegetable Seed Life Expectancy*, right.

Table 5–5.
Vegetable Seed Life Expectancy

1 to 2 Years	3 to 4 Years		5+ Years
Corn	Asparagus	Fennel	Cucumbers
Leeks	Beans	Kale	Endive
Okra	Beets	Mustard	Lettuce
Onions	Broccoli	Peas	Muskmelons
Parsley	Brussels sprouts	Pumpkins	Radishes
Parsnips	Cabbages	Rutabagas	
Peppers	Carrots	Spinach	
Rhubarb	Cauliflower	Squash	
	Celery	Tomatoes	
	Chinese cabbage	Turnips	
	Eggplant	Watermelons	

Keep in mind that seed vigour declines more rapidly than germination. If seed is past its prime, it may still germinate, but the seedlings will be weaker, slow to establish and more prone to disease.

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Transplanting

For many vegetable crops in Ontario, transplanting offers a number of advantages over direct seeding. Transplanted crops mature faster, giving growers access to early markets. Long-season vegetable crops such as tomatoes, peppers, eggplant and melons usually yield significantly more when they are transplanted.

Transplants are also quick to establish a canopy in the field, giving plants a valuable headstart on the weeds. This is particularly valuable in crops where weed control options are limited.

Not all vegetable crops are well suited to transplanting. The level of management required for successful transplant production varies with crop type. See Table 5–6, *Relative Ease of Transplanting Vegetables*, below.

Table 5–6.
Relative Ease of Transplanting Vegetables

Crop	Characteristics
Easy	
Beets, broccoli, cabbages, Brussels sprouts, chard, lettuce, tomatoes	Efficient in water absorption; rapid formation of new roots.
Moderate	
Eggplant, leeks, onions, peppers, celery, cauliflower	Young plants do not absorb water as efficiently, but new roots form quickly.
Difficult	
Muskmelons, watermelons, cucumbers, squash, sweet corn	Root system is easily injured during transplanting and resumes growth slowly; require special care.

Table 5–7. Suitable Tray Sizes for Various Vegetable Species

Crop	Tray Size	Cells /ft^2	Cells /m^2	Production Notes
Early-market tomatoes	24	14	151	Usually seeded in 288s or 406s and transplanted to large tray at first true leaf.
	38	23	248	
	50	31	334	
Mid-to-late-season tomatoes	128	78	840	Direct seeded in tray.
	288	175	1,884	
Processing tomatoes	200	122	1,313	According to processor specifications.
	288	175	1,884	
	406			
Early peppers	50	31	334	Transplant seedlings or direct seed in tray.
	72	47	506	
Mid-to-late-season peppers	128	78	840	Direct seed in tray.
	200	122	1,313	
Early brassica crops	72	47	506	Direct seed in tray.
	98			
Mid-to-late-season brassica crops	128	78	840	Direct seed in tray.
	200	122	1,313	
Cucumbers, melons, squash	24	14	151	Direct seed in tray. Do not allow plants to elongate in the greenhouse.
	128	78	840	
Cooking onions	200	122	1,313	Direct seed in tray; seedlings should be clipped several times to produce a stocky transplant.
	288	175	1,884	
	338			

Trays

Most commercial vegetable transplants are grown in plastic trays, usually in the range of 30–288 cells per tray. Various types and sizes are available. For recommended tray sizes, see Table 5–7, *Suitable Tray Sizes for Various Vegetable Species*, above.

In general, larger cells are used for early crops. They produce a bigger, more mature transplant, resulting in earlier yields. They are also more expensive to produce. Smaller cells are used for mid-to-late-season crops. They are cheaper to produce, but smaller cell volume makes water and nutrient management critical.

Tray Disinfection

For transplants grown under contract, the terms may specify that new trays be used for each crop. In other cases, growers may choose to use trays for more than one season. Trays must be thoroughly sanitized before being reused. They must also be structurally and chemically able to withstand both the disinfection treatment and another season of handling.

There are two effective ways to sanitize used trays:

Solarization: Clean, stack and cover trays with cloth or plastic. Leave them in the greenhouse during the summer. The heat will dry disease organisms. Use square-celled trays, to minimize the amount of growing media left in the trays from the previous use.

Chemical Disinfectants: Wash trays individually to remove particles of growing media. After washing, dip or spray them with a disinfectant, according to manufacturer's recommendations. Chlorine bleach can also be used. Dipping bulk lots of trays into a cleaning solution has not proven successful.

Caution: Bleach residues on the trays can damage the seedlings. Rinse trays thoroughly after disinfecting with bleach.

Growing Media

Growing media must be:

- sterile (free of insects, pathogens, nematodes, weed seeds)
- uniform
- well-drained
- lightweight
- convenient for storage and handling
- non-crusting
- able to hold water well
- free of large pieces of bark or twigs

Many commercially prepared soil-less mixtures meet these criteria. The commercial mixtures generally contain peat moss, perlite, vermiculite and a wetting agent. Some also contain fertilizer (nutrient charge). The fertilizer content of different mixtures may vary greatly. To manage the fertilizer program, you must know the nutrient content of the growing media. Avoid mixtures containing slow-release fertilizer or high nutrient charges; they can restrict the flexibility of a fertilizer program.

Seeding and Germination

Vegetable transplants are generally sown one seed per cell, usually at a depth of about twice their diameter. See Table 5–8, *Vegetable Transplant Requirements*, on page 41, for information on seeding depth, temperature, pH and time required for producing various types of vegetable transplants.

Table 5–8.
Vegetable Transplant Requirements

Vegetable	Seed Required for 10,000 Transplants g (oz)	Seeding Depth cm (in.)	Germination Temperature °C (°F)[1]			Days to Germination[2]	Optimum Growing Temperature °C (°F)		pH Tolerance	Time (weeks)
			Min	Opt	Max		Day	Night		
Broccoli	57 (2)	0.6 (¼)		29 (84)		4	16–21 (61–70)	10–16 (50–61)	6.0–6.8	4–7
Brussels sprouts	57 (2)	0.6 (¼)		27 (81)		5	16–21 (61–70)	10–16 (50–61)	5.5–6.8	4–7
Cabbages	57 (2)	0.6 (¼)	7 (45)	29 (84)	35 (95)	4	16–21 (61–70)	10–16 (50–61)	6.0–6.8	4–7
Cauliflower	57 (2)	0.6 (¼)	7 (45)	27 (81)	29 (84)	5	16–21 (61–70)	10–16 (50–61)	6.0–6.8	4–7
Celery[3]	28 (1)	0.15–0.3 (⅛)	16 (61)	21 (70)	21 (70)	7	18–24 (64–75)	16–18 (61–64)	6.0–6.8	10–12
Cucumbers	567 (20)	1.3 (½)	16 (61)	35 (95)	35 (95)	3	21–24 (70–75)	16–18 (61–64)	5.5–6.8	2–4
Eggplant	113 (4)	0.6 (¼)	24 (75)	29 (84)	32 (90)	5	21–27 (70–81)	18–21 (64–70)	5.5–6.8	5–7
Lettuce	28 (1)	0.3 (⅛)	4.5 (40)	24 (75)	27 (81)	2	13–18 (55–64)	10–13 (50–55)	6.0–6.8	4
Muskmelons	567 (20)	1.3 (½)	24 (75)	32 (90)	35 (95)	3	21–24 (70–75)	16–18 (61–64)	6.0–6.8	3–5
Onions	85 (3)	0.6 (¼)	10 (50)	24 (75)	35 (95)	4	16–18 (61–64)	8–15 (46–59)	6.0–6.8	8–12
Peppers	198 (7)	0.6 (¼)	18 (64)	29 (84)	35 (95)	8	18–24 (64–75)	15–18 (59–64)	5.5–6.8	5–9
Squash	1,475 (52)	1.3–1.9 (½–¾)	21 (70)	35 (95)	35 (95)	3	21–24 (70–75)	16–18 (61–64)	5.5–6.8	2–4
Tomatoes	85 (3)	0.6 (¼)	16 (61)	29 (84)	29 (84)	5	18–24 (64–75)	15–18 (59–64)	5.5–6.8	5–8
Watermelons	1,475 (52)	1.3–1.9 (½–¾)	21 (70)	35 (95)	35 (95)	3	21–27 (70–81)	18–21 (64–70)	5.0–6.8	2–4

[1] Germination may be possible for many vegetables at lower or higher temperatures, but percentage, speed and uniformity of germination will suffer.

[2] Under optimum germination temperatures. Primed seed will germinate faster than unprimed seed under most conditions.

[3] Daily fluctuation to 16°C (61°F) or lower at night is essential.

Aim for quick, uniform germination. Best results can be obtained by:

- watering trays with warm water (27°C–28°C or 81°F–82°F) immediately after seeding
- placing trays in a germination chamber, maintained at the optimum temperature for that crop
- moving trays out of the germination chamber as soon as the seed coat has cracked and the shoot begins to emerge

Transplant Growth and Development

It is difficult to raise multiple crops within the same greenhouse if they have different environmental requirements (temperature, ventilation, light, water, fertility). If possible, grow crops with dissimilar requirements in different areas of the greenhouse where they can be managed as required.

Temperature

Vegetable crops vary in their response to temperature. The optimum day and night growing temperatures for a number of crops are listed in Table 5–8, *Vegetable Transplant Requirements*, above.

Warm-season vegetable crops such as tomatoes, peppers, eggplant and vine crops are susceptible to chilling injury when transplants are exposed to temperatures above freezing, but below 10°C (50°F) for an extended period of time. Chilling causes stunting of growth and can have long-lasting effects on field establishment and fruit set.

Table 5–9.
Acceptable Ranges of Water Quality and Correction Methods

Factor	Range	Correction
pH	5.5–6.5	Acid can be used to lower the pH.
Bicarbonate level	60–100 ppm	Acid can be used to lower the bicarbonate reading. Every 60 ppm of bicarbonate needs 7 L of phosphoric acid (85%)[1] or nitric acid (67%)[2] per 100,000 L of water.
EC (Electrical conductivity)	<0.6 mmho/cm in straight water 1.0–2.0 mmho/cm with fertilizer added	The fertilizer program can be adjusted to maintain a safe EC.
Nitrate levels	Normally less than 20 ppm	Adjust the fertilizer program accordingly.
Sulfates	Normally 150–250 ppm	
Chlorides	Normally 20–400 ppm	

[1] Use no more than 7 L of phosphoric acid per 100,000 L of water to avoid crop problems (stretching). Use nitric acid for neutralizing more than 60 ppm bicar bonate.

[2] Each 7 L of nitric acid will contribute 14 ppm of nitrate nitrogen to the irrigation water. Adjust the nitrogen fertilizer rate accordingly

Height Control

Excessive stem elongation can be caused by low light conditions as well as excessive heat, fertilizer or water. "Pillowing" is uneven growth that results from differences in air circulation and watering between cells within trays.

Control plant height by managing the day/night temperature fluctuations in the greenhouse. Night temperatures that exceed day temperatures reduce stem elongation. Adjusting morning temperatures to 4°C–5°C (7°F–9°F) lower than the night-time temperature will give good height control. Avoid chilling temperatures with warm-season vegetable crops.

Restricting phosphate can also effectively restrain transplant growth in the greenhouse. However, excessive phosphate reductions may result in slower field establishment after transplanting.

Watering

Plug transplants should be watered thoroughly in the morning and "spot-watered" as necessary in the afternoon. Avoid watering late in the day. Disease problems increase when plants remain wet overnight. Disease organisms can be present in surface or wellwater sources. Use chlorinated water if possible. Water should be in the 15°C–20°C (59°F–68°F) range to prevent shocking the plants.

The amount and frequency of watering will vary depending on cell type, growing media, greenhouse ventilation and weather conditions. Water thoroughly and moisten the entire plug to promote root growth to the bottom of the plug. Allow the plug to dry down before watering, but do not let the plant wilt.

Water Quality

Submit a water sample to an accredited lab for analysis prior to the growing season. The greenhouse fertilizer program may have to be adjusted according to the pH, bicarbonate level and nutrient content of the water supply. See Table 5–9, *Acceptable Ranges of Water Quality and Correction Methods*, above.

If high-quality water is not available, obtain an alternative water supply.

Transplant Fertility

Vegetable transplants are usually fertilized with soluble fertilizer, applied in the irrigation water. See Table 5–10, *Analysis for Various Soluble Fertilizers*, below, for a list of fertilizers commonly used in transplant production. Use fertilizers that supply most of the nitrogen in nitrate form. Avoid fertilizers with a high concentration of urea.

Table 5–10.
Analysis for Various Soluble Fertilizers

Fertilizer Analysis	Rate for 100 ppm N (g/100 L of water)	Parts per Million			EC mmho/cm[1]
		N	P	K	
20-20-20	50	100	43	83	0.40
20-10-20	50	100	21	83	0.60
20-8-20	50	100	17	83	0.75
17-5-19	59	100	12	92	1.00
15-5-15	67	100	14	83	0.70
14-0-14	71	100	0	83	0.85

[1] Electrical conductivity of a 100 ppm solution in micromhos. The EC values were determined with a conductivity meter using distilled water. The EC values obtained will vary depending on the background EC of the water source.

Table 5–11. Vegetable Transplants Fertility Guidelines

Crop	Fertility Guidelines
Tomatoes	Very responsive to fertilizer, excess fertility will reduce transplant quality. If feeding at every watering, use a fertilizer concentration of 50–100 ppm N, depending on the stage of development. There may be some advantage to feeding less often at a higher concentration.
Peppers	Require more fertilizer than tomatoes. If feeding at every watering, use approximately 100 ppm N; increase the concentration if feeding less often.
Brassica crops	Do not require as much fertilizer as other crops. One application per week of 100–150 ppm N should be sufficient under most conditions.
Vine crops	Have a relatively short growing cycle compared to other transplant crops. Use 100–150 ppm N at weekly intervals for a total of 2–4 applications.

A high concentration of phosphate (P_2O_5) may promote excessive stem elongation. Use a fertilizer with a low-to-medium phosphate concentration, or use a fertilizer with no phosphate for most feedings and apply a high-phosphate fertilizer once every four or five feedings to promote growth. Do not withhold phosphate completely, as this will delay field establishment.

Vegetable crops vary in their response to fertilizer. The feeding program must be modified for different crops. Adjust the fertilizer program based on the nutrient content of the growing media, the water analysis and the cell size (larger cells require less fertilizer). See Table 5–11, *Vegetable Transplants Fertility Guidelines*, above.

Toxicities and Deficiencies

Nutrient deficiencies are more common than nutrient toxicities. Many growers are very cautious about over-fertilizing for fear of "burning" the roots or stems. Phosphorous-deficient transplants show very definite purple colouration along the stem and underside of leaves. Plants that have too little nitrogen will have pale-green foliage. Too much nitrogen will result in very white stems and dark-green leaves. For more information, see Chapter 1, *Vegetable Crop Fertility*.

Soluble salts in the fertilizer water may prevent germination or damage the young seedlings. On older seedlings, salt-injured plants are often stunted. Burning and root damage are other common symptoms of salt injury. Salts are measured by the electrical conductivity (EC) of the water. Table 5–9, *Acceptable Ranges of Water Quality and Correction Methods*, on page 42, lists a range of acceptable EC levels.

Hardening-Off

It is important to prepare transplants for the harsher environment of the field by hardening them off. This is especially important for early-season plantings.

Reduce greenhouse temperatures to harden-off transplants. Warm-season crops should not be hardened at temperatures below 13°C (55°F). Cool-season crops can be hardened at lower temperatures. Certain brassica crops can be susceptible to "bolting" or "buttoning" in the field if the transplants are exposed to prolonged temperatures below 10°C (50°F).

Slightly reduce water, as part of the hardening process. Do not let plants wilt excessively. They must be actively growing for good field establishment. Increasing air movement around the transplants also assists in the hardening process.

If there is no risk of frost, consider holding plants outside for several days before field planting. This allows them to become accustomed to field conditions while they are still in their trays. Select a location that is exposed to full sunlight but is protected from drying winds. Check plants regularly and water as required.

Do not harden off plants by withholding fertilizer, as this can result in nutrient deficiencies and delay field establishment. Slow-to-establish plants are more susceptible to insects, diseases and poor growing conditions.

Storage of Plug Transplants

Research has shown that, if properly stored, tomato transplants can be held for up to 2 weeks with little reduction in plant stand or vigour. Either return them to the greenhouse or store them outside. Storage in an enclosed trailer or barn for more than 1 or 2 days will result in very soft, elongated plants.

During storage:

- Elevate the racks to prevent root growth through the bottom of the plugs.
- Bring the plants inside if there is a risk of frost.
- Fertilize if planting is delayed by more than 5–7 days. A low-phosphorus, soluble fertilizer such as 20-8-20 or 20-10-20, applied in the irrigation water according to manufacturers directions, is suitable for this purpose.

Disease Management

The primary means of controlling diseases on vegetable transplants is by seed treatment, sanitation and by managing the greenhouse environment to suppress disease development.

Seed treatment with hot-water, acid or chlorine may help reduce bacterial and fungal pathogens on the seed. Acid and chlorine disinfection is very difficult to do on-farm. Seed can be damaged if protocols are not followed exactly. In most circumstances, growers must trust their seed supplier to perform the seed disinfection effectively. For more information on seed treatment methods, see the OMAFRA Factsheet, *Bacterial Diseases of Tomato,* Order No. 05-069.

All vegetable seed should be treated with a fungicide to help prevent seed decay and damping-off. See the individual commodity sections, starting on page 67, for a list of recommended chemical seed treatments.

Certain transplant or greenhouse crops should not be raised in close proximity, as one may act as a source of disease or as an alternate host for insect vectors. Avoid growing tomato transplants close to greenhouses used for flowers or greenhouse cucumbers. Pepper and tomato transplants should not be raised in the same greenhouse complex.

Never produce field transplants in the same greenhouse as commercial greenhouse vegetable crops (i.e., tomatoes, peppers and cucumbers).

Insect Management

Insects such as aphids and thrips may transmit disease into and within the greenhouse. Fungus gnat and shore fly larvae can cause damage by feeding on seedling roots and by spreading damping-off organisms.

Monitor for thrips and aphids. Hang blue sticky traps close to the seedling canopy. Indicator plants (such as potted petunia for tomato spotted wilt virus) can be placed at the ends of the greenhouse.

For more information on managing insects and diseases on transplants, see the individual commodity sections in Chapter 9, starting on page 67.

Greenhouse Sanitation

Sanitation is an important component of insect and disease control. Dirt and residue left from the previous crop may harbour pests. This increases the risk of an outbreak occurring in the next crop. The greenhouse, all work surfaces and equipment should be thoroughly cleaned and disinfected after every crop. For more information see the section *Storage Sanitation*, on page 50.

Herbicide Injury

Greenhouses should be equipped with a sprayer dedicated to herbicides only and a separate sprayer for fungicides and insecticides. Contamination may cause serious damage to greenhouse plants.

Avoid spraying weeds outside the greenhouse during the growing season. Herbicide mist or fumes may drift or be drawn into the greenhouse. Transplant trays left outside may be inadvertently sprayed. Trays stored near herbicides can also absorb fumes. Once contaminated, trays cannot be cleaned effectively.

6. Food Safety and Storage

On-Farm Food Safety

Ontario growers take pride in producing safe and wholesome fruit and vegetables. On-farm food safety and traceability programs demonstrate to buyers that food is grown with quality and safety in mind.

Food safety programs are voluntary measures taken during production, processing, storage and distribution. These good agricultural practices help growers prevent, reduce or eliminate food safety hazards.

Food Safety Hazards

A hazard is any agent associated with food that has the potential to cause an adverse health effect. These hazards include biological, chemical and physical food contaminants.

Microorganisms

Microorganisms such as bacteria, viruses and parasites present the greatest food hazard risk when fruit and vegetables are consumed raw. Some microbes that have been associated with fruit and vegetable outbreaks in the past include *E. coli* 0157:H7, salmonella, hepatitis A and cryptosporidium.

Chemical Hazards

Chemical hazards include pesticide residues on produce that exceed the maximum residue limits, contamination from disinfectants, hydraulic fluids or other chemicals used on the farm. All chemical products used during the production, handling or preparation of food must be used according to government regulations and manufacturer's labelled instructions.

Allergens are chemical hazards due to the presence of allergenic agents. Some individuals may have an allergic response to natural or foreign chemicals present in food. The most common allergic reactions are caused by nuts, sesame seeds, dairy products, eggs, fish, shellfish, soy, wheat and sulphites. Allergenic agents may occur naturally or be introduced through cross-contamination during handling and packaging.

Physical Hazards

Physical hazards include any foreign object (metal, wood, stones, glass) from the environment or equipment that could end up in fruit and vegetables. These objects could come from machinery, harvesting and packing equipment, hunters (e.g., shotgun casings), broken containers, etc.

For more information, see the OMAFRA Factsheet, *Managing Risk on Farms Open to the Public,* Order No. 06-087.

Good Production Practices

Be aware of the risks and address potential problems before they occur to help ensure the production of safe food. Many of the good production practices for food safety also complement existing agricultural best management practices. These practices will help reduce post-harvest losses, while maintaining high-quality production in a sustainable environment.

In fruit and vegetable production, good production practices are aimed at reducing risks associated with the use of pest control products, manure and water.

Pest Control Products

When using a pest control product, take the time to read the label and follow all label directions. Apply the correct rate of product, and follow the days-to-harvest guidelines. Calibrate sprayers regularly. Do not store any pest control products in the same building as the packing line or storage. Keep accurate pesticide and weather records.

Manure and Compost

Manure and compost provide valuable nutrients and benefits to the soil. However, manure and improperly managed compost can be a potential source of pathogen contamination. If compost is used, be familiar with proper compost management for pathogen reduction. If you purchase manure or compost, ask questions or get a certificate of analysis for the product. If you produce compost, document the process.

Incorporate manure immediately after application. Maximize the time between application and harvest to ensure that the manure has fully broken down in the soil before the crop is harvested. For fresh market fruits and vegetables, allow at least 120 days between the application of manure and harvest. Be aware of the potential for contamination of crops by windblown debris from feedlots and manure

Table 6–1.
Variability of Water Quality

Water Source Type	Quality Variability
River or stream	High
Pond filled by stream, ditch or runoff	High
Lake	Medium
Pond filled by ground water, spring or well	Medium
Well supplying directly to irrigation system	Low
Municipal water source	Low

storages. Do not allow runoff from barnyards or manure storages to contaminate the field or the packing area.

For more information, see the OMAFRA Factsheets:

- *Manure Composting as a Pathogen Reduction Strategy,* Order No. 05-021
- *Agricultural Composting Basics,* Order No. 05-023

Water

In fruit and vegetable production, water is frequently used for irrigation, evaporative cooling, frost protection, packing and washing. When assessing water usage on the farm, consider the source of the water, when and how the water is used, and the type of produce.

How the water looks or smells is not a reliable indicator of its safety. For produce cooling, washing and packing, use water that meets drinking water quality standards. Test wash water sources for contaminants on a periodic basis. Many growers choose to chlorinate their wash water, to further reduce the risk of contamination. See the section *Washwater Sanitation*, on page 50.

Table 6–1, *Variability of Water Quality*, above, describes the level of variability typically associated with each water source.

For more information, see the OMAFRA Factsheet, *Improving On-Farm Food Safety Through Good Irrigation Practices,* Order No. 05-059.

Worker Health and Hygiene

Harmful microbes are spread on hands and gloves or through coughing or sneezing. Pay attention to the personal hygiene and health of field and packing-house workers:

- Provide worker training on hand washing and personal hygiene.
- Keep toilets and hand-washing facilities clean and well stocked.
- Locate toilets in close proximity to the workers. Do not allow waste water to contaminate fields.
- Develop a system to report sickness and other conditions that could increase the risk of contamination.

Food Safety Programs and Certification

There are a number of food safety assurance programs available to growers. The food safety program a producer chooses will depend upon a number of factors, including ease of implementation, cost and what the buyer requests. Certification programs usually require a self-inspection using a prepared checklist followed by an external or third-party audit.

Canadian Programs

Developed by National Producer Organizations, these voluntary on-farm food safety programs are being implemented across the country. The Canadian Horticultural Council (CHC) and the Ontario Fruit and Vegetable Growers Association (OFVGA) are responsible for developing on-farm food safety programs for vegetable growers. For more information, see the Canada Horticultural Council website at www.hortcouncil.ca/OFFSMnls.htm.

Traceability

Traceability is the ability to trace product from the field to the consumer. Producers have a number of reasons to keep records tracking the production and distribution of their product.

By itself, traceability will not produce a safer product; however, it can help identify a problem quicker and allow the producer to resolve it faster. Traceability can also be part of marketing foods. A thorough bookkeeping system can verify attributes such as organic, country-of-origin, earth-friendly and fair trade.

Biosecurity

Biosecurity is the protection of Canada's economy, environment and society from pests and disease. It includes trying to prevent the introduction of new pests and diseases and eradicating or effectively managing the spread of those that have already arrived. As a producer, taking common sense precautions to prevent disease from coming onto the farm is a worthwhile investment. Some precautionary protocols include purchasing plant stock and seed from known, reputable sources.

Cooling and Storage

Cooling

Rapid and efficient cooling is the most effective tool for improving the quality and shelf-life of fresh vegetables. There are several cooling methods available for different sizes of operations and types of crops being grown. Table 6–2, *Vegetable Cooling Methods*, right, lists the suggested cooling methods for many vegetable crops.

Room Cooling

Containers of produce are placed into a refrigerated room and cold air from the evaporator coils slowly cools the product. The main advantage of room cooling is that produce can be cooled and stored in the same room. The major disadvantage is that it takes considerable time and highly perishable produce may suffer quality loss.

Forced-Air Cooling

This method is the most widely adaptable and fastest cooling method for small-scale operations. Cold air is forced to move rapidly through the containers, allowing the cold air to be in direct contact with the warm produce.

Hydrocooling

Cold water is an effective method for quickly cooling a wide range of vegetables in containers or bulk bins. Hydrocoolers use either an immersion or a shower system to bring products in contact with the chilled water. Hydrocooling avoids product water loss and may even add water to a slightly wilted commodity.

Package Icing

Some vegetables are cooled by filling the packed containers with crushed or flaked ice. Initially, the direct contact between the ice and product causes fast cooling. However, as the ice in contact with the product melts, the cooling rate slows considerably. Package icing is less efficient than forced air or hydrocooling. Using liquid-ice, a slurry of ice and water, distributes ice throughout the container, achieving better contact with the product.

Vacuum Cooling

This method involves water evaporation at very low atmospheric pressure. Vegetables that have a large surface area-to-volume ratio, such as lettuce and leafy greens, are best suited for vacuum cooling. There is approximately 1% product weight loss (mostly water) for every 6°C of cooling, and thus some coolers are equipped with a water spray system that adds water to the product surface during cooling.

Table 6–2.
Vegetable Cooling Methods

	Large Operations					Small Operations			
	RC	FA	HC	PI	VC	RC	FA	HC	PI
Asparagus		✓	✓			✓		✓	
Bean		✓	✓				✓		
Broccoli		✓	✓	✓			✓		✓
Brussels sprouts		✓	✓	✓			✓		✓
Cabbage		✓			✓		✓		
Carrots (with tops)		✓	✓	✓			✓	✓	
Carrots (without tops)			✓	✓			✓	✓	✓
Cauliflower		✓	✓	✓			✓		✓
Celery			✓		✓		✓	✓	
Cucumber	✓	✓					✓		
Eggplant	✓	✓				✓	✓		
Garlic	✓					✓			
Herbs		✓					✓		
Leafy greens		✓	✓		✓		✓		
Muskmelon		✓	✓	✓			✓		
Onion (dry)	✓					✓	✓		
Onion (green)			✓	✓	✓				✓
Pea		✓		✓	✓		✓		✓
Pepper	✓	✓			✓		✓		
Potatoes	✓					✓			
Squash (summer)	✓	✓					✓		
Squash (winter)	✓					✓			
Sweet corn			✓	✓	✓		✓	✓	✓
Sweet potato			✓			✓			
Tomato	✓	✓					✓		
Watermelon		✓	✓				✓		

FA – Forced-air cooling
PI – Package icing
VC – Vacuum cooling
HC – Hydrocooling
RC – Room cooling

Storage Life for Fresh Vegetables

Storage Tips

- Keep several thermometers in the storage area to help ensure the area is being uniformly cooled. Calibrate thermometers regularly to ensure that fresh produce is stored properly. Thermometers set into ice water should read 0°C (32°F).
- Change the wash water regularly when washing fresh produce. This prevents the build-up of bacteria and other pathogens. Use chlorine at 150–200 ppm to help prevent rot from getting started.
- The quality of the produce coming out of storage will reflect its quality going in.

To preserve the quality of harvested vegetables and improve the marketing of crops, store vegetables properly immediately after harvest. Rapid, uniform cooling to

Table 6–3.
Storage Life for Fresh Vegetables in Commercial Storage

Commodity	Temperature		Relative Humidity (%)	Approximate Storage Life	Commodity	Temperature		Relative Humidity (%)	Approximate Storage Life
	°C	°F				°C	°F		
Asparagus	0–2	32–37	95–100	2–3 weeks	Melons				
Beans, green or snap	7–10	45–50	95	7–10 days	Honey dew	7	45	90–95	3 weeks
Beans, lima	3–5	37–40	95	5–7 days	Muskmelons ($^{3}/_{4}$-slip)	2–5	37–40	95	15 days
Beets, topped	0	32	98–100	4–6 months	Muskmelons (full slip)	0–2	32–37	95	5–14 days
Broccoli	0	32	95–100	10–14 days	Watermelons	10–15	50–59	90	2–3 weeks
Brussels sprouts	0	32	95–100	3–5 weeks	Mushrooms	0	32	95	3–4 days
Cabbage, Chinese	0	32	95–100	2–3 months	Okra	7–10	45–50	90–95	7–10 days
Cabbages, early	0	32	98–100	3–6 weeks	Onions, dry	0	32	65–70	1–8 months
Cabbages, late	0	32	98–100	5–11 months	Onions, green	0	32	95–100	3–4 weeks
Carrots, bunched	0	32	95–100	2 weeks	Onions, sets	0	32	65–70	6–8 months
Carrots, immature	0	32	98–100	4–6 weeks	Parsley	0	32	95–100	2–2.5 months
Carrots, mature	0	32	90–98	7–9 months	Parsnips	0	32	98–100	4–6 months
Cauliflower	0	32	95–98	3–4 weeks	Peas, green	0	32	95–98	1–2 weeks
Celeriac	0	32	97–99	6–8 months	Peppers, chili (dry)	0–10	32–50	60–70	6 months
Celery	0	32	98–100	2–3 months	Peppers, sweet	7–13	45–55	90–95	2–3 weeks
Chard	0	32	95–100	10–14 days	Potatoes, chipping	10	50	90–95	10 months
Chicory, witloof	0	32	95–100	2–4 weeks	Potatoes, early crop	4	39	90–95	7 days
Collards	0	32	95–100	10–14 days	Potatoes, late crop	4	39	90–95	5–10 months
Corn, sweet	0	32	95–98	5–8 days	Potatoes, seed	2–4	37–39	90–95	7 months
Cucumbers	7–13	45–55	95	10–14 days	Pumpkins	10–15	50–59	50–70	2–3 months
Eggplants	7–13	45–55	90–95	1 week	Radishes	0	32	95–100	3–4 weeks
Endive and escarole	0	32	95–100	2–3 weeks	Rhubarb	0	32	95–100	2–4 weeks
Garlic	0	32	65–70	6–7 months	Rutabagas	0	32	98–100	4–6 months
Greens, leafy[1]	0	32	95–100	10–14 days	Salsify	0	32	95–98	2–4 months
Horseradish	–1.0–0	30–32	98–100	10–12 months	Spinach	0	32	95–100	10–14 days
Kale	0	32	95–100	2–3 weeks	Squashes, summer	5–10	41–50	95	1–2 weeks
Kohlrabi	0	32	98–100	2–3 months	Squashes, winter	10–15	50–59	50–70	1–6 months
Leeks	0	32	95–100	3–6 months	Sweet potatoes	13–16	55–61	85–90	4–7 months
Lettuce	0	32	98–100	2–3 weeks	Tomatoes, firm-ripe	7–13	45–55	90–95	4–7 days
					Tomatoes, mature-green	13–21	55–70	90–95	1–3 weeks
					Turnips	0	32	95	4–5 months

[1] Leafy greens may be stored for 2–3 weeks if they have been hydro-cooled immediately after harvest.

remove field heat, followed by storing under proper conditions will ensure that a quality product reaches the consumer or processor.

See Table 6–3, *Storage Life for Fresh Vegetables in Commercial Storage*, above, for recommended storage conditions for individual crops.

Ethylene

Ethylene is naturally produced by most fruit and vegetables once harvested and put into storage. It acts as a growth regulator and a ripening agent. Ethephon is a commercially available, synthetically produced ethylene product. It is widely used in the processing tomato industry (see the section *Chemical Fruit Ripening*, on page 207).

Ethylene gas increases the rate of ripening of mature fruits and vegetables, and shortens shelf-life. The effects of ethylene gas depend upon:

- the stage of produce maturity
- the temperature and relative humidity of the storage room
- the concentration of ethylene
- the exposure time

Ethylene is an invisible and odourless gas, however, its detrimental effects on produce can be easily misdiagnosed. Some of the undesirable effects of ethylene are:

- loss of green colour in some immature fruits (e.g., cucumbers and summer squash) and leafy vegetables
- accelerated ripening of fruits (e.g., tomatoes) during handling and storage
- russet spotting on lettuce
- bitterness (isocoumarin) in carrots
- sprouting of potatoes
- abscission of leaves (e.g., cauliflower, cabbage)
- toughening of asparagus

There are many sources of ethylene in the environment. The more important ones include internal combustion engines and ripening produce. Other sources include fluorescent ballasts, decomposing produce, cigarette smoke and rubber materials exposed to heat or UV light.

Use electric rather than gas-powered fork lifts where ethylene-sensitive commodities are present. Isolate internal combustion engines from handling and storage areas. Do not let engines idle in an enclosed loading space.

Simple ventilation of handling areas can prevent ethylene build-up, as long as the incoming air is not polluted. One complete air exchange per hour is usually sufficient.

Ethylene can be used to your advantage when controlled and careful ripening of fruits and vegetables is desired. In this case, commercially available ethylene generators are used.

For more information, see the OMAFRA Factsheets:

- *Storage of Cabbage*, Order No. 90-055
- *Troubleshooting Cold Storage Problems*, Order No. 94-083
- *Sizing and Laying Out a Short-Term (Summer) Refrigerated Storage for Fruits and Vegetables*, Order No. 92-124
- *Tunnel Forced-Air Cooler for Fresh Fruits and Vegetables*, Order No. 98-031

Chilling Injury

Chilling injury occurs when a commodity is exposed to temperatures below its ideal storage range. The minimum storage temperature for each crop varies, as do the symptoms of chilling injury.

Table 6–4. Chilling Injury-Sensitive Vegetable Crops

Commodity	Min. Storage Temperature		Chilling Injury Symptoms
	°C	°F	
Asparagus	0–2	32–36	darkened, water-soaked tips leading to bacterial soft rot
Basil	7–10	45–50	wilting, water-soaked appearance
Beans (snap)	7–10	45–50	russeting, pitting, corky centres
Cantaloupe	2–5	36–41	pitting and surface decay
Cucumber	7–10	45–50	pitting and surface decay
Eggplant	7–13	45–55	flesh browning, pitting, decay of cap, fruit rot
Okra	7–10	45–50	pitting, discolouration, decay
Pepper	7–13	45–55	water-soaked appearance, darkening, fruit rot
Potato	2–10	36–40	browning, sweetening
Pumpkin	10–15	50–59	pitting, rot
Sweet potato	10	50	flesh discolouration, off-flavours, hard core, increased decay
Tomato (ripe)	7–13	45–55	rubbery texture, watery flesh, seed browning, decay
Tomato (mature green)	13	55	irregular ripening, poor texture
Watermelon	10–15	50–59	surface pitting, loss of flavour, fading of red colour
Winter squash	10–15	50–59	pitting, poor flavour, increased rot
Zucchini (summer squash)	5–10	41–50	surface pitting, rapid decay

Chilling injury is not always easily recognized at the farm gate. Chilled produce often looks fine as it is removed from storage. However, as the temperature increases (in the grocery store or after purchase), symptoms begin to develop, and quality is quickly compromised.

Chilling injury may occur at any stage of the production and distribution line. The longer the chilling event, the more significant the level of injury. The effects of multiple, short periods of chilling may be cumulative in some commodities. See Table 6–4, *Chilling Injury-Sensitive Vegetable Crops*, above.

For more information, see the OMAFRA Factsheet, *Chilling Injury of Horticultural Crops*, Order No. 98-021.

Commodity Compatibility

Not all crops should be stored together, even if they have the same storage requirements. Some crops will give off volatile substances that interfere with the successful storage of others. For example, apples, pears, peaches, plums, apricots and tomatoes give off ethylene gas which, even in low concentrations, can cause undesirable effects in

Table 6–5.
Proven Disinfectants

Disinfectant	Rate	Pros	Cons
Sodium hypochlorite (bleach 5.25 to 6% active)	1 part to 9 parts water	Inexpensive Readily available Quick	Corrosive Less effective when mixed with high pH water Residues may be toxic to plants if not rinsed properly. inactivated by organic matter
Quaternary ammonium (DCD, chemprocide)	1 mL per 300 mL water	Non-corrosive Effective at low temperatures Can be combined with detergents	Residues may be toxic to plants if not rinsed properly.
Phenolic compounds (hospital disinfectants)	See label.	Provide residual activity	Expensive
37% formalin solution	3L per 100 L water		Requires a respirator during application. Fumes are toxic to plants. Ventilate following treatment.

many vegetables (see the section *Ethylene*, on page 48). Potatoes may impart an earthy flavour to fruit, particularly at high temperatures. Do not store incompatible commodities in the same building unless special ventilation arrangements have been made.

Washwater Sanitation

Water is needed in many vegetable-packing systems to move, clean or cool produce. Inadequate sanitation of this water can lead to higher levels of postharvest decay and food safety concerns. Chlorine is an effective sanitizer when used as outlined below:

- Start with drinking water quality water.
- Maintain free chlorine concentration between 100 and 150 ppm.
- Maintain washwater solution pH between 6.5 and 7.5.
- Change water daily or when it becomes turbid or cloudy cloudy (organic matter deactivates chlorine).
- Monitor free chlorine levels and pH constantly (minimum every hour).

Sodium hypochlorite, calcium hypochlorite and chlorine gas can be used in washwater sanitation. Note that chlorine gas decreases the water pH while sodium hypochlorite and calcium hypochlorite increases water pH.

If the water pH requires adjustments, they can be made using muriatic acid (HCl) or citric acid.

Storage Sanitation

Cleaning and sanitation in horticultural storage and packing areas are extremely important. Crop residue left from season to season is a prime source of the pathogens that cause post-harvest rots. Dried bacterial slime and fungal spores will survive on the walls and other surfaces for years. A good sanitation program involves three steps: cleaning, disinfecting and rinsing.

Cleaning

Remove debris, such as soil, wood, stones and metal, by brushing, vacuuming, scraping and high-pressure washing. High-pressure wash with hot, soapy water. Water should be at least 38°C (100°F). Cleaning compounds such as soaps reduce the surface tension of water so that dirt and debris may be loosened and flushed away.

Disinfecting

Disinfecting follows the cleaning step. Cleaning must be done before disinfecting. Dirt and residue will prevent the disinfectant from coming into contact with all surfaces. Many common disinfectants are deactivated by organic matter.

There are many products and procedures for sanitizing storages and equipment. See Table 6–5, *Proven Disinfectants*, above, for a short list of proven disinfectants. Exposure time is generally 10 minutes, however this may vary with the chosen disinfectant. See the label for specific instructions.

Wear protective clothing (waterproof garment, safety glasses, rubber boots and gloves) during disinfecting and check the product label for specific safety instructions.

Rinsing

Rinse from the top down with clean (preferably drinking-quality) water. Leave the storage area open to air dry. If possible, force outside air into the area. This will help remove unpleasant odours that may be transferred to the produce next season.

For more information on storage sanitation, see the Agriculture and Agri-Food Canada Factsheet, *Hygiene Measures in Fruit and Vegetable Storage Warehouses.*

7. Integrated Pest Management

Integrated pest management (IPM) is an approach to managing pests that utilizes all available strategies to reduce pest populations below an economic injury level. IPM does not advocate a continuous pesticide spray program to eradicate pests. Instead, it promotes the integration of cultural, biological and chemical control strategies. By using these pest control strategies, the adverse effects of pesticides on the environment are minimized, and economic returns are maintained.

An IPM program makes control decisions based on:

- the pest (identification, biology and behaviour)
- beneficial organisms
- monitoring techniques
- use and timing of appropriate management tools
- resistance management strategies
- recordkeeping

In this publication, use and timing of chemical and cultural management tools and resistance management strategies are outlined.

More detailed information on pest identification, biology, trapping, monitoring and recordkeeping techniques can be found in OMAFRA publications such as:

- Publication 700, *Integrated Pest Management for Onions, Carrots and Lettuce in Ontario: A handbook for growers, scouts and consultants* (Video also available).
- Publication 701, *Integrated Pest Management for Crucifers in Ontario: A handbook for growers, scouts and consultants* (Video also available).
- Publication 12, *Sweet Corn Production Manual.*

Current information is also available on the crop page of OMAFRA's website at ontario.ca/crops. Additional information is supplied via newsletters, meetings, field monitoring, demonstrations and pest management workshops. For more information on available IPM programs, contact OMAFRA's Agricultural Contact Centre at 1-877-424-1300, or the nearest OMAFRA Resource Centre.

Thresholds

An IPM program uses control guidelines (thresholds) that indicate when pesticides should be applied to prevent economic losses. Timing of control measures is critical. Spray guidelines for insect pests are based on an economic threshold where the lost income from not applying a control will be higher than the cost of applying a control. In other words, some damage to the crop is tolerated, as long as this damage does not exceed the cost of the control. Thresholds for diseases, weeds, nematodes and vertebrates may be based on weather, site history, stage of crop development and field observations.

Monitoring

Monitoring is critical for the successful implementation of any IPM program. Monitoring allows growers to forecast and evaluate potential pest problems. Effective monitoring identifies the pest present, estimates its population and recognizes conditions favourable for pest development and damage.

Monitoring allows accurate timing of pest control measures, thus reducing pesticide use. Regular monitoring will also help identify minor or secondary pest populations before they cause significant damage.

Monitoring can include the use of traps and/or visual scouting. Good recordkeeping is an essential component of any IPM program. Keep a site map and records of:

- status of crop health and stage of crop
- population levels of pests and beneficials
- damage observed
- location of damage
- weather and other environmental conditions
- sprays and other control measures used

Trapping

Traps are useful for indicating the presence or absence and the relative abundance of insects. However, they often catch only the adult stage of the pest and may not provide information on the damaging immature stages.

Weather monitoring can improve trapping efficiency by predicting insect emergence and development.

Traps are usually placed in the field 1–2 weeks prior to the estimated emergence of the insect. Both pheromone traps and visual traps are commonly used in vegetable crops. Pheromone traps use a female sex hormone lure to attract male adults. The lure is specific to each insect species, which makes insect identification easier. Visual traps rely on a visual lure, such as a bright yellow sticky card, to attract the pest.

It is critical to the success of the trapping program that the correct type of trap is used for each target pest. The number of traps and the location within the field will also depend on the crop and insect. Specific monitoring guidelines are available in the publications listed at the beginning of this chapter.

Keep in mind that pheromone lures are specific to the pest being trapped. They are very sensitive to contamination if they come into contact with other types of pheromones. If your trapping program involves using different types of pheromones, wear disposable latex gloves to prevent cross-contamination during handling.

Scouting

One of the best ways to keep track of insects or the amount of disease present in the crop is to visually inspect the field. Scout fields at least once a week. More frequent monitoring is recommended when the pest is most active. Weed surveys taken across the field will aid in the selection of weed management strategies. Tools such as a hand lens or sweep nets can improve insect and disease scouting efficiency.

When scouting the crop, inspect plants in several different areas across the field for an accurate estimate of pest pressure. Pay special attention to the border areas and fencerows. These areas are favoured overwintering sites for many insect pests. Scouting guidelines (aimed at a specific crop or pest) often indicate the number of plants that should be inspected during scouting operations. In general, a minimum of 30 plants (sometimes as many as 50 to 100) should be inspected across the field before making any pest management decisions.

For a list of available crop consultants providing monitoring services, contact OMAFRA's Agricultural Contact Centre at 1-877-424-1300, or the nearest OMAFRA Resource Centre.

Pest Control Measures

Cultural and Mechanical

Integrated pest management incorporates cultural and mechanical practices to prevent or delay the development of pest outbreaks. Management tools include:

- site selection
- crop rotation
- resistant/tolerant cultivars
- certified, treated seed
- sanitation
- elimination of alternative hosts
- inter-cropping
- water management
- optimized plant health

The individual commodity sections in Chapter 9, starting on page 67, offer specific information utilizing all of the available management practices to prevent and manage pests.

Crop Rotation for Control of Diseases

Crop rotation can be an important practice for preventing some diseases caused by fungi, bacteria and nematodes. Rotation with a non-susceptible crop for 3 years usually allows enough time for plant material in the soil to completely decompose. In the absence of susceptible plant material, these organisms die off. For some soil-borne pathogens, such as phytophthora in peppers and vine crops, a rotation longer than 3 years may be required.

Rotation only works when successive crops are not susceptible hosts. It is important to remember that plants in the same family (for example, potatoes, tomatoes, peppers and eggplant) may all be susceptible to the same disease organisms. Do not rotate with plants in the same family.

Diseases that are spread by wind or by insects are generally not controlled by rotation. Many leaf blight organisms and powdery mildew fungi can blow into fields from neighbouring weeds and infested fields.

Chemical Controls

Chemical controls include synthetic, inorganic and biological pesticides. They kill target pests and limit subsequent populations. They are important tools for crop protection when used as part of an IPM program.

Understand the pest's life cycle and apply chemicals at the stage when the pest is most vulnerable. Select the appropriate product for the target pests.

To control insects, monitor fields closely. Spray according to action thresholds or at critical stages of crop development.

To control disease, apply protective fungicides prior to disease infection and development. Use factors such as weather conditions, crop stage and (where available) disease prediction models to indicate fungicide spray timing.

Prevent Bee Poisoning

It is important to protect bees when you spray. Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops also offer bees important sources of nectar for honey production.

If you choose to use insecticides for insect control, take these steps to prevent harming bees when you spray:

- Before you apply a pesticide, advise local beekeepers, so that they take additional precautions to protect the bees. Contact the Provincial Apiarist at 1-888-466-2372 for a list of the beekeepers in your area.
- Do not spray any flowering crop on which bees are foraging. If you must apply insecticides, spray after 7 pm when the bees are not foraging. If this is not a possibility, spray before 7 am.
- Do not apply insecticide on windy days, to prevent drift.
- When there is a choice, choose the product formulation that is less hazardous to bees. Dusts are more toxic than sprays. WP formulations are more toxic than EC formulations.
- Under the *Bees Act,* it is an offence to spray in orchards while there is bloom on the trees.

Most organophosphate and carbamate insecticides are highly toxic to bees. Examples of insecticides used in crop production that are very toxic to bees are listed in Table 7–1, *Relative Toxicity of Insecticides to Honeybees,* right.

Read each pesticide label for specific precautions regarding bees.

Table 7–1.
Relative Toxicity of Insecticides to Honeybees

Product(s)	Active Name
Highly Toxic **Do not apply to flowering crops.**	
Admire	imidacloprid
Agri-Mek 1.9EC	abamectin
Alias 240 EC	imidacloprid
Cygon 480AG; Lagon 480E	dimethoate
Decis 5EC	deltamethrin
Diazinon 500 E, Diazinon 50W	diazinon
Dibrom	naled
Furadan 480F	carbofuran
Imidan 50WP	phosmet
Lannate	methomyl
Lorsban 15 G, Lorsban 4 E, Lorsban 50W, Pyrifos 15 G, Pyrifos 50 W, Pyrinex 480 EC	chlorpyrifos
Malathion 25W, Malathion 500 E	malathion
Matador 120EC	cyhalothrin-lambda
Monitor	methamidophos
Orthene	acephate
Pounce	permethrin
Pyramite	pyridaben
Ripcord 400 EC	cypermethrin
Sevin XLR	carbaryl
Success 480SC	spinosad
Vydate L	oxamyl
Moderately Toxic **Apply only during late evenings or early mornings.**	
Assail 70WP	acetamiprid
Endosulfan 50W, Thiodan 4EC, Thiodan 50WP, Thionex 50WP	endosulfan
Pirimor 50DF	pirimicarb
Supra Captan 80 WDG, Maestro 80 DF	captan

Beneficials

Beneficials are natural enemies of the crop pest. These predators (including parasites and pathogens) help suppress pest populations.

Beneficials will not completely eliminate damage by pests. However, once they are established, they can maintain pest populations at lower levels. They are also effective at controlling indirect pests such as aphids, leafhoppers and mites. They are less effective at keeping populations of direct pests (those attacking the harvested product) at levels acceptable for commercial production. One of the advantages of beneficial insects is that their activities can prevent or delay the development of pesticide resistance. Where possible, select chemical control products that will not harm the beneficials.

Table 7–2.
Insecticide Groups Based on Sites of Action

The classification scheme listed below is adapted from
the Insecticide Action Committee Mode of Action Classification (IRAC) V5.3 (July 2007).

Group #	Primary Site of Action	Group Name	Product name (s)
1A[1]	Acetylcholine esterase inhibitors	carbamate	Furadan 480 F, Lannate TNG, Pirimor 50 DF, Sevin XLR, Vydate L
1B		organophosphate	Agrox B-2, Agrox CD, Counter 15 G, Cygon 480, Diazinon 50 W, Diazinon 500 E, Dibrom, Imidan 50 WP, Lagon 480, Lorsban 4E, Lorsban 15 G, Malathion 25 W, Malathion 500 E, Monitor 480, Orthene 75 SP, Pyrifos 15 G, Pyrifos 50 W, Pyrinex 480 EC, Thimet 15 G
2A	GABA-gated chloride channel agonists	chlorinated cyclodiene	Thiodan 4 EC, Thiodan 50 WP, Thionex 50 W
3	Sodium channel modulators	diphenylethane	Kelthane 50 W
		pyrethroid	Decis 5 EC, Force 3.0 G, Matador 120 EC, Methoxychlor 240, Pounce 384 EC, Ripcord 400 EC
4	Nicotinic acetylcholine receptor agonists	neonicotinoids	Admire 240 F, Assail 70 WP, Actara 240 SG, Actara 25 WG, Alias 240 EC, Cruiser 5 FS, Gaucho 480 FL, Intercept, Poncho 600
5	Nicotinic acetylcholine receptor agonists (allosteric, not group 4)	naturalyte/spinosyns	Success 480 SC, Entrust 80 W
9B	Compounds of unknown or non-specific mode of action (selective feeding blockers)	pyridines	Fulfill 50 WG
15	Inhibitors of chitin biosynthesis, type 0, Lepidopteran	benzoylureas	Rimon
17	Chitin biosynthesis inhibitor (diptera only)	cyromazine	Citation 75 WP, Governor 75 WP
21	Mitochondrial complex 1 electron transport inhibitor	botanicals	Rotenone 5, Rotenone 1% WP, Rotenone 5% WP
23	Inhibitors of lipid synthesis	tetronic acid derivatives	Forbid 240 SC

[1] Although sharing the same primary target site, it is possible that not all members of a single major mode of action (MoA) class have been shown to be cross-resistant. However, for the purposes of this classification system, it should be assumed that cross-resistance exists between compounds in any one sub-group.

Resistance Management

Resistance occurs when a pest is able to survive exposure to a pesticide that previously controlled it. Resistance to a pesticide develops after repeated exposure to a specific chemical or chemical family. A few naturally occurring resistant individuals survive after each spray, while the susceptible portion of the population is killed. These resistant survivors multiply and gradually replace the susceptible ones. Eventually the resistant population dominates, and the pesticide loses efficacy.

There are many potential causes for pest control failures. Before assuming a population is resistant to a product, consider the following factors: product selection, water volume, rate, calibration and coverage, timing, water pH, time required for knockdown of pest and weather conditions.

Resistance to pesticides can develop very quickly. Do not use the same chemical repeatedly unless it is used in rotation with a different chemical or used in combination with other chemicals having a different mode of action.

Many chemicals with the same active ingredients are marketed under different brand names. For example, the insecticide chlorpyrifos is marketed under the brand names Lorsban, Pyrifos and Pyrinex.

Different chemicals may also have the same mode of action. For example, both Assail and Admire have the same mode of action. Using Assail after Admire is equivalent to using Assail after Assail, since resistance to both chemicals develops at the same time, even though only one may have been used repeatedly.

Certain insects and diseases are more prone to develop resistance to fungicides than others. Pests with a short life cycle and many generations per growing season as well as those that multiply very quickly are more likely to develop resistance. Fungicides with a single mode or site

Table 7–3.
Fungicide Groups Based on Mode of Action

This classification scheme is based on the Fungicide Resistance Action Committee (FRAC) List, 2007

Group #	Primary Site of Action	Group Name	Product Name(s)	Risk of Developing Resistance
1	Inhibition of mitosis (turbulin formation)	methyl-benzimidazole carbamates	Senator 70 WP	High
2	Affect cell division, DNA & RNA synthesis & metabolism	dicarboximide	Ronilan EG, Rovral WP	Moderate to High
3	Inhibition of sterol synthesis	DMI (demethylation inhibitor)	Nova 40 W, Tilt 250 E, Topas 250 E, Mission 418 EC, Bumper 418 EC	Moderate
4	Affect RNA synthesis	Phenylamides)	Allegiance FL, Apron FL, Apron XL LS, Ridomil 1G, Ridomil Gold 480 EC, Ridomil Gold MZ, Ridomil Gold MZ 68 WP	High
7	Fungal respiration	carboxamide	Lance WDG, Vitaflo 280	Moderate
9	Methionine biosynthesis	anilino-pyrimidines	Scala SC, Switch 62.5 WG	Medium
11	Fungal respiration	quinone outside inhibitors (QoI)	Cabrio EG, Headline EC, Quadris, Reason 500 SC, Tanos 50 DF	High
12	Osmotic signal tansduction	phenylpyrroles	Maxim 480 FS	Low to Moderate
14	Lipid peroxidation (proposed)	aromatic hydrocarbon chlorophenyl	Botran 75 W, Quintozene 75 WP	Low to Moderate
21	Fungal respiration	quinione inside inhibitors (Oil)	Ranman 400SC	Medium to High
22	Mitosis and cell division	benzamide	Gavel 75 DF, Zoxium 80W	Low to Moderate
25	Protein synthesis	antibiotic	Streptomycin	High
27	Unknown	cyanoacetamide oxime	Curzate 60 DF, Tanos 50 DF	Low to Moderate
28	Cell membrane permeability (proposed)	carbamate	Tatoo C	Low to Moderate
29	Uncoupler of oxidative phosphorylation		Allegro 500 F	
33	Unknown	phosphonate	Aliette WDG	Low
40	Cell wall synthesis (proposed)	cinnamic acid amides	Acrobat 50 WP	Low to Medium
M1	Multi-site, contact	inorganic	Copper Spray, Copper 53 W, Kocide DF, Kocide 2000, Oxidate, Parasol WP	Low
M2	Multi-site, contact	inorganic	Microscopic Sulphur	
M3	Multi-site, contact	dithiocarbamate	Acrobat 50 WP, Dithane, Dithane F 45, Ferbam 76 WDG, Gavel 75 DF, Manzate DF, Penncozeb 80, Polyram DF, Thiram 75 WP, Vitaflo 280, Zineb 80 W	Low
M4	Multi-site, contact	phthalimide	Agrox B-2, Agrox CD, Captan, Maestro 75 DF, Supra Captan 80 WDG	Low
M5	Multi-site, contact	chloronitrile	Bravo 500, Tatoo C	Low
NC	Not Classified	Not classified	MilStop	Unknown

of action are more prone to resistance developing than fungicides with multiple modes of action.

See Table 7–2, *Insecticide Groups Based on Sites of Action*, on page 54, and Table 7–3, *Fungicide Groups Based on Mode of Action*, above, for a list of chemical families and their modes of action.

The pest control recommendation tables in Chapter 9, *Crop Management Recommendations*, starting on page 67, list the chemical group for each control product. Over the course of the season, rotate between products from different chemical groups.

Steps to Delay the Development of Pesticide Resistance

- Rotate between products from different chemical groups. Avoid the repeated use of any pesticide or group of pesticides.
- Follow the pesticide label. Many products make specific recommendations about the maximum number of sequential applications and the maximum number of total applications permitted in one season.
- When applying a pesticide, follow the appropriate rate, timing, water volume, nozzle selection and water pH.
- Ensure the sprayer is well maintained and properly calibrated.
- Follow an IPM program that makes use of a variety of different pest management strategies, including monitoring, crop rotation, cultural, biological and chemical options.
- Spray insecticides only when necessary. Use established thresholds where available.
- Apply fungicides preventatively before disease occurs. Wherever possible, follow disease prediction models. Applying fungicides in an attempt to eradicate a disease after it has become established can increase the risk of selecting for resistant populations of the pathogen.
- When tank-mixing pest control products, ensure that each component belongs to a different chemical group with a different mode of action.
- If you experience a control failure after using a registered product, do not reapply the same pesticide.
- Keep accurate records of the type of product used during each application throughout the season.

Resistance can be costly to the grower. The development and registration of new products is expensive and time-consuming. Judicious use of pesticides will help reduce the development of resistant populations and conserve the effectiveness of existing products.

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Spraying Vegetable Crops

Water Volumes

Generally, most insecticides/fungicides are applied with about 135–450 L/ha (12–40 gal/acre) of water. Herbicide applications range from 55–350 L/ha (5–30 gal/acre). Many fungicide labels specify a specific minimum water volume to ensure adequate coverage and optimize the product's performance.

Table 7–4.
Sample Droplet Size Classification Chart

	PSI					
Examples of Nozzle Types	**40**	**50**	**60**	**70**	**80**	**90**
Hollow cone	F	F	F	VF	VF	VF
Flat fan	M	M	F	F	F	F
Drift reducing flat fan	C	C	M	M	M	M
Low pressure air induction flat fan	C	C	C	M	M	M
High pressure air induction flat fan	XC	XC	XC	XC	VC	VC

Nozzle Selection

All agricultural spray nozzle manufacturers classify the range of droplet sizes produced by each of their nozzles. Tables or charts are used by the nozzle manufacturers to show droplet size classification factoring in the nozzle type, nozzle size and operating spray pressures (psi).

Common classifications include:

VF = Very Fine
F = Fine
M = Medium
C = Coarse
VC = Very Coarse
XC = Extremely Coarse

Most fungicides and insecticides require medium or medium-to-fine spray droplets. Droplets that are too small may be easily carried off by the wind or evaporate before hitting the target, resulting in poor spray coverage. Coarse or very coarse sprays are useful to prevent spray drift of herbicides, however, they may not provide sufficient coverage for insecticides or fungicides.

To reduce the potential for spray drift, manufacturers now offer a wide range of drift-reducing nozzles that deliver the same amount of spray as conventional nozzles but produce a coarser droplet spectrum.

Table 7–4, *Sample Droplet Size Classification Chart*, above, is an example of droplet size charts often used by nozzle manufactures. It is important to select the right type of nozzle and be able to operate it at the right pressure to produce the droplet size needed for the job.

Flat fan nozzles provide uniform spray distribution across the whole boom. They are frequently used for herbicide applications on boom-type sprayers. Flat fan nozzles are becoming more common for fungicide and insecticide application. The pumps on many large sprayers cannot produce sufficient pressure to properly operate a hollow cone nozzle. An increasingly wide selection of flat fan nozzle types produce a medium or medium-to-fine spray at operating pressures less than 100 psi.

Hollow cone nozzles have generally been used to apply fungicides or insecticides. This type of nozzle produces a finer and more uniform spray distribution than solid cone nozzles. Hollow cone nozzles are particularly suited to the application of wettable powders, flowables and suspensions.

Solid cone nozzles are used when increased penetration into the crop canopy is required.

Air Temperature and Relative Humidity

Pesticides can cause phytotoxicity or burning of plant foliage or flowers if applied during very hot weather (above 27°C or 81°F). In hot conditions, avoid applications between 10:00 AM and 2:00 PM, as plants will be more prone to injury. The water droplets themselves can, at times, act as tiny magnifying lenses causing plant injury. Spraying during hot conditions may also cause a large portion of the spray droplets to evaporate before they hit the target.

During conditions of high relative humidity, the drying of the spray materials will be delayed. Slow and prolonged drying of pesticides can lead to phytotoxicity in some instances.

Also note that synthetic pyrethroid insecticides (Ripcord, Decis, Pounce, Matador, etc.) break down quickly when air temperatures are above 27°C (81°F), reducing their effectiveness. If possible, apply these in the evening, when temperatures have dropped, or select a different product.

Rainfall

The decision to spray just prior to a rain or shortly after should be based on plant protection. This may be more critical when applying fungicides. All fungicides are most effective if the leaf is adequately covered prior to infection. Waiting for the rain to stop before the initial application may allow disease organisms to invade unprotected plant tissue. Once they have dried, most fungicides can withstand about 2.5 cm (1 in.) of rainfall and still provide adequate protection.

Many preemergent herbicides are best applied before a rain. Moist soils allow for better distribution of the herbicide within the seed zone. Post-emergent applications are best applied after a rain or should be timed to allow adequate drying prior to rainfall.

Wind Speed & Drift

When applying fungicides and insecticides, moderate air movement helps move the product in and around the crop. In addition, light winds will help in the drying process. Optimum air movement is 3–8 km/h.

To prevent unwanted drift, avoid spraying when the wind speed is more than 11 km/h. Drift is also possible at lower wind speeds and no-wind conditions. Drift potential is affected by the interaction of travel speed, wind speed and droplet size. For more information on preventing pesticide drift, see the section, *Manage Drift*, on page 210.

8. General Diseases and Insects of Vegetable Crops

There are a number of pests that attack a wide range of crops. Descriptions of the common pests and cultural control methods are listed here.

For chemical control methods, see the individual commodity sections in Chapter 9, *Crop Management Recommendations*, on page 67.

Diseases

Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)

Crops Affected: Most vegetable crops.

Symptoms: Seedlings affected by damping-off generally rot at ground level and topple over. Other symptoms may include seed decay, rotting roots and cankers on lower petioles.

Plants are usually infected by damping-off during the seedling stage. Cool, wet springs and conditions conducive to slow emergence and early development are particularly problematic.

Root rots generally occur during periods of warm, wet weather and may affect the plant at any stage of development. Certain species of fusarium and rhizoctonia cause root rot problems during hot, dry conditions.

Thresholds: None established.

Management Notes: Sterilize flats and soil for growing seedlings (see the section *Transplanting*, on page 39). Use fungicide-treated seed and plant only when soil and weather conditions are favourable for vigourous crop development. See also Table 5–3, *Minimum Soil Temperatures for Vegetable Seed Germination*, on page 38.

See the commodity sections of Chapter 9, starting on page 67, for seed treatment recommendations.

Viruses (General)

Crops Affected: Most vegetable crops.

Viruses can cause significant problems in vegetable crops. Some viruses are spread by insect pests. Examples include cucumber mosaic and bean common mosaic. For virus symptom identification, see the specific crop sections in Chapter 9.

Depending on the crop, virus diseases may be spread by aphids and or other leaf-feeding insects, such as the cucumber beetle. Insects can carry and transmit a virus for their entire life (persistent transmission) or they can acquire a virus during feeding (non-persistent transmission).

In persistent transmission, an insect can become infected after feeding on an infected plant for an extended period of time (at least several minutes to 1 hour). After an incubation period (sometimes several days or weeks), the insect is able to spread the virus for the rest of its life. These viruses are often found where the insect pest has formed large colonies on a plant. A good insect management program including pesticides can be useful in dealing with persistent virus diseases. For example, the western flower thrips spreads the tomato spotted wilt virus through persistent transmission.

Non-persistent transmission occurs when an insect lands on and samples plant tissues from many different plants. The insect picks up the virus from an infected plant and transfers it to the next plant. As the insect feeds, it clears the virus from its mouthparts and is no longer able to transmit the disease to additional plants. Soybean aphids are a common vector of many non-persistent viruses.

Unfortunately, once the problem is identified, the aphids have moved on, making insecticide applications inefficient at controlling the problem. The use of clean seed, resistant varieties and the management of alternative hosts, including weeds, can reduce sources of viruses in the field. Most of the common viruses infecting vegetable crops are non-persistent viruses.

Insects

Aphids

Crops Affected: Most vegetable crops.

Symptoms/Identification: Aphids are small, pear-shaped insects, with cornicles or "tail-pipes" near the tip of their abdomen. They are typically found in colonies located on the underside of the leaf or along the stem or petioles. Aphids pierce the leaves and suck the sap from many vegetable crops. Severe feeding causes leaf distortion.

Aphids produce a sticky substance called "honeydew," which can promote the development of secondary moulds (sooty mould). These moulds may affect marketability.

Aphids also act as a primary vector of several economically significant virus diseases (see comments under *Viruses (General)*, on page 59). Non-colonizing aphids move through the crop in search of suitable host plants, spreading the virus as they feed. With many viruses, the disease infection occurs after less than 1 minute of feeding.

The soybean aphid does not form colonies on vegetable crops. However, it often will move through vegetables in its search for soybeans, spreading non-persistent viruses as it travels. The control of aphid populations with conventional insecticides does little to prevent the spread of non-persistent viruses.

Period of Activity: Aphids are present throughout most of the growing season. However, populations build quickly during hot, dry weather. Aphid populations are often kept below threshold levels where predators (ladybird beetles, lacewings, minute pirate bugs, etc.) are present in abundance.

Thresholds:

Peppers	No threshold is established, but more than 10 aphids per leaf could be potentially damaging.
Sweet corn	10% of ears infested (ears with more than 20 aphids are considered infested.)
Tomatoes	5 aphids per 10 leaflets per plant
Potatoes[1]	4 aphids per leaf (check 1 lower leaf on 50 plants)

[1] Keep seed potato fields free of aphids at all times.

Management Notes: The continuous use of broad-spectrum insecticides may disrupt beneficial populations, resulting in aphid resurgence. Note that the sunflower aphid and the green peach aphid may have developed resistance to insecticides in some areas.

For more information, see the OMAFRA Factsheet, *Aphids Infesting Lettuce and Celery in Ontario*, Order No. 00-053.

Cutworms

Crops Affected: Many vegetable crops.

Symptoms/Identification: There are several species of cutworm. The larvae are soft and fat, and they roll up when disturbed. Look for cutworm larvae in the top 2.5 cm (1 in.) of soil surrounding the damaged plant. Early-season cutworms attack the seedling plants, usually cutting them below or at the soil surface. A single larva may destroy several seedlings.

Period of Activity: Most species of cutworms feed at night, hiding during the day under loose stones or in the soil near the base of the plant. Plants at the seedling stage are most vulnerable to cutworm losses.

The variegated cutworm appears later in the season. It is larger than the other cutworm species and feeds on the foliage of tomatoes, potatoes, peppers and eggplant, as well as damaging and contaminating tomato fruit.

Black cutworms may cause serious damage in potatoes by feeding on the tubers late in the season.

Thresholds: For most vegetable crops, the control guideline is 5% damaged plants.

Other thresholds are as follows:

Cutworm

Potatoes	Sporadic pest. Monitor populations with pheromone traps.
Sweet corn	10% damage, if plants are less than 4–6 leaves and larvae are less than 4 cm (1.5 in.)

Variegated cutworm

Tomatoes (scouting)	1 larva per 30 plants
Tomatoes (pheromone traps)	7 moths per trap[1] per week

[1] Use delta or wing traps in combination with field scouting.

Management Notes: Migrating female moths are attracted to weedy fields in the early spring for egg-laying. Damage is often sporadic.

Cutworm control is most effective on small (less than 2.5 cm or 1 in.) larvae. Larger larvae are difficult to control with insecticides. At more mature stages (>2.5 cm or 1 in. in length), they cease feeding as they prepare to pupate, and control becomes unnecessary.

Apply insecticides in the early evening, as the cutworms come to the surface to feed at night. Insecticides are more effective on moist soils.

See the individual commodity sections in Chapter 9, starting on page 67, for cutworm chemical control recommendations.

For more information, see the OMAFRA Factsheet, *Managing Cutworms in Vegetable Crops*, Order No. 00-055.

Seedcorn Maggot

Crops Affected: Seedcorn maggots are generalist feeders and attack a wide variety of vegetable crops, including beans, cucurbits, nappa cabbage, onions, potatoes and sweet corn.

Symptoms/Identification: These small white maggots feed on the swollen, ungerminated seed of vegetable crops. Poor stand establishment is often a symptom of infestation.

Seedcorn maggot flies will lay eggs inside the heads of nappa cabbage during hot, dry conditions. Larvae then feed on the inside head leaves, creating a ragged appearance, rendering the heads unmarketable.

Period of Activity: Maggots are usually a problem in direct-seeded crops during cool, wet springs when germination is delayed. The first generation of adult flies lay their eggs from April until the middle of June. There are several generations per year in Ontario, however, the first generation is generally the most damaging.

Thresholds: None established.

Management Notes: Use one of the insecticide-seed treatments recommended in the commodity sections of Chapter 9. Egg-laying females are attracted to moist soils and the odour of decaying organic matter. Discourage egg-laying by applying manure or incorporating winter cover crops well in advance of planting.

Slugs

Crops Affected: Beans, celery, brassica crops, eggplant, leafy vegetables (lettuce, chicory, endive), peppers, potatoes, rhubarb, sweet corn and tomatoes.

Symptoms/Identification: These soft-bodied, legless, grey mollusks feed above or below ground, depending on the soil moisture level. Slugs have rasping mouth-parts and will create ragged holes on the lower leaves, sometimes leaving a "window-pane" of waxy cuticle behind.

Severely affected plants may become skeletonized. Under high populations, slugs also attack seeds and emerging seedlings. A slime trail is usually observed at the feeding location.

Period of Activity: Slug damage is most severe in years when there is prolonged cool, wet weather during May and June.

Thresholds: None established.

Management Notes: Most plants can successfully outgrow light feeding damage. Cultivating fields where slug pressure is high can help reduce the slug population. Tillage exposes the slugs to dehydration and predation by birds and mammals.

Removing weeds and crop residue from the zone immediately surrounding young seedlings may also help reduce damage. Zone tillage can remove slug habitat while maintaining the benefits of reduced tillage.

See the commodity sections of Chapter 9, starting on page 67, for chemical control recommendations.

Tarnished Plant Bug

Crops Affected: The tarnished plant bug (TPB) feeds on over 300 species of fruit, vegetable and field crops, as well as numerous weed species. Most crops discussed in this publication are susceptible to attack. Problems with TPB may occur in beans, celery, brassica crops (including specialty crucifers), cucurbits, eggplants, lettuce, peppers, potatoes and tomatoes.

Symptoms/Identification: TPB nymphs and adults cause a broad range of damage on vegetable crops. Symptoms include:

- stings and lesions on celery stalks
- reduced fruit set on beans, peppers and eggplants
- stings and blemishes on tomato and pepper fruit
- necrotic spots on the florets and curd of broccoli, cauliflower
- small holes with brown margins on lettuce leaves
- dead leaves on potatoes and vine crops

Period of Activity: The TPB is a sporadic pest, present in Ontario throughout the growing season. Adults are highly mobile, moving readily from adjacent crops when disturbed by harvest activities.

Thresholds:

Celery and lettuce	0.1 to 0.2 TPB per plant
Tomatoes	1 nymph or adult per 30 plants (after fruit set)

Management Notes: TPBs breed on many common weed species, including chickweed, dandelion, lamb's-quarters, ragweed and fleabane. Weed control in and around vegetable plantings will help reduce potential infestations.

For more information, see the OMAFRA Factsheet, *Tarnished Plant Bug Damage on Vegetable Crops in Ontario*, Order No. 98-025.

Wireworm

Crops Affected: Carrots, onions, sweet corn, potatoes, vine crops, eggplant, potatoes, tomatoes, peppers, sweet potatoes and sugarbeets.

Symptoms/Identification: Wireworms are the larvae of click beetles. The larvae are copper-coloured, cylindrical and hard-bodied. They have 3 pairs of tiny legs near the head-end and are commonly confused with multi-legged millipedes and symphalans. Wireworms can be seen burrowing into the ungerminated seeds, as well as underground roots and stems of plants. Infested plants do not develop well, and seedlings lack vigour or fail to emerge. Damage is often scattered randomly across the field. In the fall, wireworm feeding may render sweet potatoes, carrots and potatoes unmarketable.

Period of Activity: Wireworms are present all season. Young plants are most susceptible, therefore early-season control is critical. Wireworms have a life cycle of several years. They are likely to be present in fields with a history of the problem or in fields that have recently had sod crops.

Thresholds: Wireworms may be monitored in the fall (or in the early spring for later-planted crops) using bait stations. Bury whole carrots, 7.5 cm (3 in.) deep, at 10 marked stations across the field. Check the stations in 2–3 days. A count of 0.5 to 1 wireworm per station indicates a potential problem. Make your planting and seed treatment decisions accordingly.

Management Notes: See the individual commodity sections of Chapter 9, starting on page 67, for a list of registered insecticide-seed treatments and in-furrow control options. Planting into well-prepared, warm soils and avoiding unnecessarily deep planting depths will help encourage early-season growth, reducing the incidence of this pest.

For more information, see the OMAFRA Factsheet, *Managing Wireworms in Vegetable Crop*, Order No. 00-047.

White Grubs

Crops Affected: Beets (table), carrots, brassica crops, potatoes, sweet potatoes and sweet corn.

Symptoms/Identification: White grubs are the larvae of the June beetle, the European chafer and (in some areas) the Japanese beetle. The grubs have six legs with a C-shaped white body and darker head. The tail end of the grub often appears dark due to soil it ingests during feeding. Severe feeding damage early in the season may cause the plant to dwarf, become wilted and die. Feeding on root crops (potatoes, beets, carrots) in the fall renders them unmarketable.

Period of Activity: European chafers (an annual grub) overwinter as early instar larvae. Peak feeding occurs in April to mid-May. Larvae pupate in the late spring, after which time they are not usually a problem in vegetable crops.

Table 8–1. Nematodes Impacting Vegetable Crops in Ontario

Nematode Species	Crops Affected	Symptoms	Thresholds
Root lesion	Most vegetables	Brownish, scratch-like wounds on plant roots. The lesions are often invaded by secondary pathogens.	tomatoes: 2,000/kg soil[1] other vegetables: 1,000/kg soil or 50/g dry root
Root-knot	Most vegetables	Galls develop on plant roots. Secondary roots grow around galls, giving the root a hairy appearance. Poor growth, patchy distribution in field.	carrot: zero tolerance root vegetables[2]: 500/kg soil (spring sample) other vegetables: 1,000/kg soil
Sugarbeet cyst	Beets, spinach, brassica crops and other root crops	Stunted plants. Outer leaves wilt, turn yellow prematurely and die. White or brown cysts can be seen on washed roots.	2,000 larvae or eggs/kg of soil, or >250 cysts/kg soil, or 200 eggs/100 g of soil
Bulb and stem	Onions, garlic, leeks, shallots	Twisted and deformed plants, with shorter, thicker leaves (known as "onion bloat") . Splitting and cracking of infected bulbs. On garlic, nematode symptoms are similar to fusarium basal plate rot.	100/kg soil

[1] Tomato threshold is for newer, processing varieties with vigorous growth. For older or fresh-market varieties, use 1,000/kg soil as the threshold.

[2] Root vegetables include parsnips, potatoes, onions and other tuberous crops.

Japanese beetles (an annual grub) overwinter as third instar larvae, which resume feeding in late spring to complete their development. Although the roots of grasses are preferred, larvae will also feed on the roots of vegetables are other crops. Adults emerge in late June and are active through August, feeding on a wide variety of crop and ornamental foliage.

June beetle larvae are present in the soil for 3 years. Feeding is most noticeable in the late spring. However, damage may occur throughout the growing season on root crops.

Thresholds: None established. Look for grubs in the crop row, approximately 5 cm (2 in.) below the soil surface. Older pupae of the June beetle larvae may feed on deeper roots, up to 25 cm (7 in.).

Management Notes: To avoid injury by white grubs, wait 2 or more years before planting vegetables on land that had been planted with grass sod. Where white grubs have been identified prior to planting (or in replant situations), consider planting to a non-host crop, such as beans. Where European chafer or Japanese beetle larvae are present, delaying planting to late spring may eliminate the problem.

Nematodes

Root-lesion, root-knot, sugarbeet cyst nematodes and occasionally the bulb and stem nematode are responsible for most nematode problems in Ontario vegetable crops. A crop may be attacked by the combined action of two or more kinds of nematodes. In some cases, the presence of nematodes exacerbates some fungal diseases. For example, the damage caused by root-lesion nematodes together with verticillium wilt of eggplants, tomatoes and potatoes is often worse than the damage caused by either pest alone.

Before deciding upon a management strategy for nematodes, complete a nematode soil test to determine the levels of nematodes present. In Ontario, nematode populations in soil and roots are usually at their highest in May–June and again in September–October. The fall months are a good time to soil sample for nematodes, as the populations are high and controls can be taken well in advance of planting the crop.

See Appendix G, *Diagnostic Services*, on page 233, for sampling and testing information.

Table 8–1, *Nematodes Impacting Vegetable Crops in Ontario*, above, outlines the various treatment thresholds associated with specific nematode species.

For more information, see the OMAFRA Factsheets:

- *Sampling Soil and Roots for Plant Parasitic Nematodes*, Order No. 06-099
- *Bulb and Stem Nematode in Onions and Carrots*, Order No. 00-043

Nematode Control

Caution

Carefully follow the manufacturer's directions for the use of soil fumigants. You must have a permit to apply methyl bromide. A permit may be obtained from the Pesticides Control Section, Ministry of the Environment, 135 St. Clair Ave. W., Toronto, M4V 1P5, Tel: 416-323-5095.

Always follow the instructions on the label carefully regarding rates and application method. Shank-injection of fumigants is preferable to reduce the chance of wind-and-odour drift, runoff or other mishaps. Muck soils often require higher rates.

Fumigate soil either in the fall or in the spring. Note that many fumigants require a 21-day plant back interval to prevent damage to the crop. At the time of fumigation, the soil temperature should be at least 4°C (39°F) at the 15-cm (6 in.) depth. Prior to application, work the soil to a depth of 20–25 cm (8–10 in.). The moisture content of the soil must be at a level that would permit good seed germination.

With fall applications, work the soil several weeks before fumigation so that the area is reasonably free from undecomposed crop residue. Do not disturb the soil after sealing until the normal spring cultural operations are started.

After spring fumigation, cultivate the soil thoroughly before planting to aerate and ensure that all traces of fumigant odour have dissipated.

Do not use nematicides containing bromine before planting onion, beet, celery or potato.

See Table 8–2, *Nematode Fumigant Control Recommendations*, on page 65.

For more information, see the OMAFRA Factsheet, *Land Preparation: A Key to Successful Soil Fumigation*, Order No. 89-177.

Birds

Bird control methods must be in place *at least* 10 days before the crop becomes attractive for feeding. This is not necessarily 10 days before the crop is ready for harvest. Once the birds have found a food source, it is very difficult to scare them away.

Birds quickly become accustomed to uniform movements and noise patterns. Moving scare devices to new locations on a regular basis will greatly improve control. The randomness of a noise device is of paramount importance. The frequency and level of the noise are secondary.

Visual Deterrents

There are several visual bird deterrents available to growers. Scare-eye balloons, flashing tape, mirrors and predator-shaped kites are generally not as effective as the noise-making repellants. However, when used in combination, they can improve the efficiency of the acoustic scare devices.

Acoustic Devices

There are three principle types of acoustic scare devices. They include propane-fired cannons, electronic sound devices and digital distress calls.

Propane-Fired Cannons

These units are most effective when the timing of the blast is randomized. The cannon should never blast at intervals of less than 3 min. Frequent intervals will only cause the birds to become accustomed to the noise. The efficiency of the bird-banger will also be increased if the unit is moved regularly.

In built-up areas, the propane-fired cannon may greatly disturb neighbours. In such a setting, the less invasive AV Alarm and Bird Gard devices may be more appropriate.

Electronic Sound Devices

The AV Alarm makes an electronic warbling sound. This noise is irritating to birds and interferes with their sensory system. In short, it makes them edgy and easily scared. These units work particularly well in combination with propane cannons. Visual repellants may also work well in combination with the AV Alarm.

Digital Distress Calls

These electronic devices play bird distress calls over a speaker system. Birds mistake the calls for a warning of danger and abandon the field. The distress call has been known to attract predator birds such as hawks. The presence of hawks flying in the area will also act to deter feeding birds.

Bird Gard units are programmable, with a selection of different bird calls to chose from. This allows the units to

Table 8–2.
Nematode Fumigant Control Recommendations [1]

Trade Name	Active Ingredients	Rate[2]		Notes
Basamid Granular	dazomet	**eggplant, lettuce, pepper & tomato**		Apply to cultivated, moist soil only. Incorporate immediately after application. Seal immediately after incorporation. Will not control cyst-nematodes. See label for appropriate planting intervals.
		seed beds:	3.25–5 kg/100 m^2	
Busan 1020	metam sodium	***seed beds:***	.75–1 L per 10 m^2	Inject into well-cultivated, moist soil only. Seal immediately after incorporation. See the label for sprinkler recommendations. Planting may take place 21 days after treatment if soil is well drained, light-textured and relatively dry and warm.
		field application:	375–935 L/ha	
Chloropicrin 100	chloropicrin	**tomatoes and peppers**	93 L/ha	Seal immediately after incorporation. Leave soil undisturbed for 10 days. Aerate for at least 5 days after cultivation.
		potatoes	55 L/ha	
Telone II	1,3 dichloropropene	**brassica crops & cucurbits**		Apply to cultivated, moist soil only. Can be broadcast over entire field or injected into specific rows to be planted. Seal soil surface immediately after application. Leave soil undisturbed for 7–14 days after application. A longer waiting period may be required if the soil is cold and/or wet.
		broadcast:		
		Mineral soil	112 L/ha	
		Muck soil	200 L/ha	
		rows:		
		Mineral soil	65 L/ha	
		Muck soil	100 L/ha	
		other vegetables		
		broadcast:		
		Mineral soil	135 L/ha	
		Muck soil	200 L/ha	
		rows:		
		Mineral soil	65 L/ha	
		Muck soil	100 L/ha	
		greenhouse beds:	2 L/100 m^2	
Telone C-17	1,3 dichloropropene and chloropicrin	***broadcast:***		Same as above.
		Mineral soil	160 L/ha	
		Muck soil	380 L/ha	
		100-cm rows:		
		Mineral soil	65 L/ha	
		Muck soil	120 L/ha	
		greenhouse beds:	2 L/100 m^2	
Vapam	metam (sodium, anhydrous)	***seed beds:***	1L /10 m^2 (apply in 80 L of water)	Apply to cultivated, moist soil only. Seal soil immediately after application. Planting may take place 21 days after treatment if soil is well drained, light-textured and relatively dry and warm.
		soil Injection:	375–900 L/ha	

[1] All toxic gases must be aerated from the soil before planting. Fumigation may temporarily raise the level of ammonia, nitrogen and soluble salts in the soil.

[2] Always refer to the label for complete instructions before applying a fumigant.

be customized to focus on the species of bird causing the problem. The distress calls are played in a random sequence, with predator calls interspersed.

Units can operate on a timer or a light sensor, deactivating them when birds are not feeding. The device runs off a 12-volt car battery. It will generally last 10 days between charging.

These units are of particular use in more built-up settings. As it sounds like the call of real birds, nearby neighbours are less likely to be disturbed by it.

Deer, Groundhogs, Raccoons and Rabbits

Deer, groundhogs and rabbits can be a serious problem in vegetable plantings, particularly in areas where woodlots or brush surround vegetable fields. Deer and groundhogs will often root for carrots in harvested fields. Raccoons are a serious pest of sweet corn. Trapping groundhogs and raccoons may help reduce the problem.

For more information on deer control, see the OMAFRA website at www.ontario.ca/crops.

9. Crop Management Recommendations

ASPARAGUS

Production Requirements

Asparagus is a long-term vegetable crop that should produce viable yields for 15 or more years. Thorough planning is essential for success. Field selection and preparation are important for long-term production.

Expected Yields

Crop	per acre	per hectare
Provincial average	3,000 lb	3,300 kg
All-male hybrid (established)	>4,000 lb	>4,500 kg

Cultivars

Consult plant and seed suppliers for descriptions of varieties and availability of plants at least 1 year before planting. A list of asparagus crown producers is available on the OMAFRA website at ontario.ca/crops.

Field Selection and Preparation

Plant into well-drained sandy or sandy-loam soils free of perennial weeds and grasses. Soil testing is highly recommended to determine fertility levels and pH before transplanting. Soil pH should range between 6.0 and 6.8. If possible, use a green-manure crop or livestock manure before planting, to increase soil organic matter. For cover crop options, see Chapter 3, *Water Management*, on page 27.

Avoid planting asparagus into fields that have previously grown asparagus. Asparagus yields decline over time due to two important *Fusarium* diseases commonly found in asparagus soils. See the section *Crown Rots (Fusarium sp.)*, on page 69, for more information.

Growing Seedlings

Soak seed in 32°C (90°F) water for 3–4 days. Dry and sow immediately into fertile, well-prepared soil. Plant seed in mid-May or once the ground is prepared and warm enough for seeding. Optimum soil temperatures for germination are 15°C–30°C (59°F–86°F.)

To allow for selection of strong plants, plan to grow more crowns than are needed. One kilogram of good seed should provide enough crowns to plant 1 ha (0.89 lb/acre).

NURSERY FIELDS

	Metric	Imperial
Row spacing:	45–60 cm	18–24 in.
In-row spacing:	8–10 cm	3–4 in.
Depth:	2.5–4 cm	1–1.5 in.
Rate:	approximately 11 kg of seed/ha	10 lb/acre

Transplanting and Spacing

Dig the 1-year-old nursery plants in early spring. Discard the weak or small crowns (less than 20 g or 3/4 oz). Up to one-third of the total crowns may be discarded. Plant crowns as soon as possible after digging.

PRODUCTION FIELDS

	Metric	Imperial
Row spacing:	1.2–1.5 m	4–5 ft
In-row spacing:	22–30 cm	9–12 in.
Depth (top of crown):	15 cm	6 in.

Fertility

Green manure crops planted in the year prior to asparagus establishment require 30–40 kg N/ha (27–36 lb N/acre) prior to or at seeding. Apply P and K based on crop requirements and soil tests.

Nitrogen

See Table 9–1, *Asparagus Nitrogen Recommendations*, below.

Table 9–1.
Asparagus Nitrogen Recommendations

	Actual N	
Method	**kg/ha**	**lb/acre**
Nursery	75[1]	67[1]
New plantings	110[2]	98[2]
Established plantings:		
Pre-harvest	55	49
Post-harvest	55	49
Total	**110**	**98**

[1] An additional 50 kg nitrogen/ha (45 lb/acre) may be applied as a side-dress application in August or early September if rainfall was excessive in the summer.

[2] Broadcast all the recommended nitrogen and potash prior to planting.

Table 9–2.
Asparagus Disease Control Recommendations[1]

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[2]	Notes
RUST						
DMI (group 3)	myclobutanil	Nova 40 W	340 g in 370 L water	136 g in 33 gal. water		Maximum 5 applications/yr.
	propiconazole	Topas 250 E	250 mL in 370 L water	100 mL in 33 gal. water	240	Apply at 14–21-day intervals. Maximum 3 applications/yr.
		Mission 418 EC	150 mL	60 mL	240	
dithiocarbamate (group M3)	zineb	Zineb 80 W	1.1–3.3 kg	0.44–1.3 kg		Apply at 5–10-day intervals. Use high rate on full-grown fern.
	metiram	Polyram DF	2.25–3.25 kg	0.9–1.3 kg		Use high rate on full-grown fern. Apply at 7–10-day intervals. Maximum 4 applications/yr.
PURPLE SPOT (STEMPHYLIUM)						
chloronitrile (group M5)	chlorothalonil	Bravo 500	3.4 L	1.36 L	190	Maximum 3 applications/yr. Will also provide rust suppression under low disease pressure conditions.
QoI (group 11)	azoxystrobin	Quadris	0.45-1.1 L	180-440 mL	180	Use high water volumes. Begin application prior to disease development. Use the low rate under low disease conditions. Spray intervals may be lengthened from 7–14 days, under low disease pressure conditions.

[1] Apply disease control products *after* the harvest season.
[2] PHI = Pre-Harvest Interval

Phosphorus

Soil tests are required to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, asparagus fields are unlikely to respond to additional phosphate applications. For soils testing less than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12. Band the phosphate below the crowns at planting.

Potassium

Soil tests are required to determine potassium requirements. Where the soil test values are 250 mg K per L soil (ppm) or higher, asparagus fields are unlikely to respond to additional potash applications. For soils testing less than 250 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Integrated Pest Management

Diseases

RUST

Identification: Look for cream to dark-reddish-brown, oval-shaped, raised pustules on the stems and fronds after harvest. Rust-coloured spores are often easily seen in the centre of the lesions.

Development: The rust fungi overwinter in the field, on crop debris. Infection of growing foliage can occur from April through to early September. Warm weather with heavy dew or light rainfall promotes rust development.

Thresholds: None established.

Management Notes: Some asparagus varieties do have moderate levels of rust resistance. The fungicides listed in Table 9–2, *Asparagus Disease Control Recommendations*, above, are best used in a preventative program.

Protect plantings as soon as the fronds are about 30 cm (12 in.) high (late May for new plantings, early July for established ones). Inspect new plantings for rust as soon as they develop fern; infected immature fields may act as a source of innoculum for the commercial plantings. Maintain a 7- to 21-day schedule until late August to protect the fern growth. Thorough coverage of the entire canopy is important.

PURPLE SPOT (STEMPHYLIUM)

Identification: Tan-to-brown, sunken, elliptical lesions with purple edges appear on infected spears, stems and fronds. Harvest infections reduce the marketability of the crop. Severe summer infections result in the premature defoliation of the fern, reducing the following year's yields by up to 52%.

Development: Stemphylium overwinters on asparagus crop residue. Infections during harvest often occur after sand-blasting or high wind have damaged the spears. These microscopic wounds act as a point of entry for the fungi. Once established, stemphylium lesions will continue to release spores for the duration of the growing season, infecting new fern as it emerges.

Management Notes: Where infection has been severe, consider destroying infected fern and plant debris, which are sources of overwintering spores. Reduced tillage and the use of cover crops and windbreaks can help reduce the occurrence of sand blasting. See Table 9–2, *Asparagus Disease Control Recommendations*, on page 68. Maintain a 7–21-day preventative fungicide program. Use the shorter spray interval during periods of cool, wet weather or prolonged heavy dewfall.

CROWN ROTS (*FUSARIUM* SP.)

Identification: Crown rots caused by *Fusarium oxysporum* and *Fusarium moniliforme* cause yield decline and can limit the productive life of an asparagus planting. *Fusarium* causes the centre of infected roots to turn brown and mushy, limiting the plant's ability to translocate water and nutrients to the fern. Eventually, the infected plants will die off.

Development: Both types of *Fusarium* are soil-borne fungi. *F. oxysporum* is found in all soils. Concentrations increase in soils over time as plants become infected. *F. moniliforme* is hosted by both asparagus and corn.

Management Notes: Avoid planting into fields that have previously grown asparagus. It will take at least 5 years after an asparagus crop for soil levels of *F. oxysporum* to decrease to baseline levels. Avoid planting where corn has been grown in the previous 3 years.

Minimize tillage and use zero-tillage practices where possible. Excessive and deep cultivations can injure crowns and increase *Fusarium* infection.

Vigorously growing asparagus plants are less susceptible to crown rots. Take care to avoid stressful growing conditions caused by overpicking, pest pressure, weed competition, soil compaction, drought stress and low fertility.

Asparagus miner larvae may transmit *Fusarium* from the soil into the plant, hastening infection.

For more information, see the OMAFRA Factsheet, *Diseases of Asparagus*, Order No. 82-045.

Insects

APHIDS, CUTWORMS

For identification and management information on these common vegetable insects affecting asparagus, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–3, *Asparagus Insect Control Recommendations*, on page 70.

ASPARAGUS BEETLE

Identification: These blue-black beetles with red wing margins and their larvae can reduce asparagus vigour by feeding on the fern during establishment and after harvest. Feeding injury and eggs laid on the spears during harvest can impact the marketable yields.

Period of Activity: Asparagus beetles overwinter as adults in crop residue and in sheltered areas such as pine windbreaks. Beetle emergence usually coincides with asparagus harvest. First generation larvae are often active after harvest, during fern establishment. A second generation of adults (and larvae) emerges in late July.

Thresholds:

Eggs:	2 eggs on 10 spears
Larvae:	50% of plants with larvae present or 10% defoliation
Adults:	5%–10% of plants infested

Management Notes: Time field-monitoring activities for the afternoon when the asparagus beetles are more active. See Table 9–3, *Asparagus Insect Control Recommendations*, on page 70.

ASPARAGUS MINER

Identification: Asparagus miners are commonly found in asparagus fields. These fly larvae create winding tunnels (mines) on the stalks just below the epidermis. The mines are normally found near the base of the plant. The larvae are pure white and range in size from 0.5–5 mm long.

Period of Activity: Miner adults emerge in early June. There are two generations per year, with peak populations normally occuring in mid-June and again in mid-August.

Table 9–3.
Asparagus Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
APHIDS						
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83 mL in 100–200 L water	33 mL in 10–20 gal water	180	**Post-harvest only.** Maximum 3 applications/yr. 24-hr re-entry interval.
carbamate (group 1A)	pirimicarb	Pirimor 50 DF	1 kg in 675 L of water	0.4 kg in 60 gal of water		**Post-harvest only.**
organophosphate (group 1B)	dimethoate[2]	Lagon 480	2.3 L in 675 L of water	0.9 L in 60 gal of water		Maximum 6 applications/yr.
		Cygon 480	2.3 L in 675 L of water	0.9 L in 60 gal of water		Maximum 6 applications/yr.
ASPARAGUS BEETLE						
pyrethroid (group 3)	deltamethrin	Decis 5 EC	200 mL in 200–500 L water	80 mL in 20–45 gal water		Apply after cutting only.
	cypermethrin	Ripcord 400 EC	86 mL	34 mL	1	Apply when beetles are first observed.
carbamate (group 1A)	carbaryl[2]	Sevin XLR	2.5–6.4 L	1–2.56 L	2	Use high water volumes. Do not treat more than once every 3 days.
organophosphate (group 1B)	malathion	Malathion 500 E	2.5 L	1 L	1	
		Malathion 25 W	5.5 kg	2.2 kg	1	
CUTWORMS						
pyrethroid (group 3)	permethrin	Pounce 384 EC	180–390 mL	72–156 mL	2	Use high rate on dry soils. Use high rate on large cutworms. Do not disturb the soil surface for 5 days after treatment.
carbamate (group 1A)	carbaryl[2]	Sevin XLR	2.5–6.4 L	1–2.56 L	2	Late-season (climbing) cutworms only. Do not treat more than once every 3 days.

[1] PHI = Pre Harvest Interval

[2] See the section *Bee Warning*, below

Bee Warning

Dimethoate is toxic to bees and should not be used during the bloom period. Carbaryl is especially toxic to bees and should not be used during the fern-growth period. With other insecticides, losses of bees can be reduced if sprays are applied in the late evening when the bees are not foraging. Advise local beekeepers of spraying activity (see the section *Prevent Bee Poisoning*, on page 53).

Thresholds: None established.

Management Notes: Miners are not usually associated with any significant plant injury or yield loss, however they may be associated with the transmission of *Fusarium* infections.

Mechanical Injury

Hooking

Bent spears are caused by a physical injury to the spear. Where sandblasting is a problem, spears will "hook" into prevailing winds. Below-ground injuries also causing hooking include cutworm feeding, inadvertent nicks from cutting knives and abrasions from sharp stones, cultivators, etc.

Fall-seeded cover crops help maintain soil organic matter while preventing both water and wind erosion the following spring. Broadcast 4 bu/ha (1.5 bu/acre) of rye in late August to mid-September. Use a burn-down herbicide in the spring, prior to spear emergence.

Physiological Disorders

Hollow Stem

This problem tends to be more prevalent in young spears during periods of warm, wet weather resulting in very rapid spear growth. Seasons with moderate temperatures and even growth will result in a low incidence of hollow stems. Although this problem does not affect the eating quality of the spear, it may reduce marketability.

Harvest

Healthy asparagus plantings can be harvested for about 10–14 days at the beginning of the third season after field setting. For example, if the field is set in the spring of 2008, the first limited harvest would be in the spring of 2010. The harvest season increases by 1–2 weeks per year, up to a maximum of 6–8 weeks.

The length of the harvest season is determined by plant vigour and spear size. Stop harvesting when 75% of the spears are smaller than 1 cm (3/8 in.) in diameter. If weeds, insects, disease or adverse weather conditions reduced plant vigour in the previous season, decrease the harvest duration accordingly.

Storage

Freshly harvested asparagus is very perishable and rapidly loses quality. Collect harvested spears from the field as soon as possible, protect them from the sun and move them to cold storage. Store under high humidity at 1°C–2°C (34°F–37°F).

Hydrocooling is an effective and rapid way of removing field heat from asparagus spears. Under good conditions, asparagus will store for 2–3 weeks.

Fern Disposal

Clip asparagus fern in the fall, leaving 15–20 cm (6–8 in.) of stubble to catch drifting snow for better crown protection. The stubble can be cut up with a rotary or flail-type mower in early spring. The fern contributes organic matter to the soil and helps prevent early-season wind erosion.

BEANS

Production Requirements

Snap beans are grown on all types of soils, with the exception of very heavy clay loams. They require well-drained locations with good fertility. A soil pH of 6.1 to 6.5 is ideal. The maturity of snap bean varieties grown in Ontario ranges from 48–78 days from planting to harvest. Harvest usually occurs 7–14 days after full bloom.

Average Yields

Crop	per acre	per hectare
Processing (green and yellow)	3 tons	6.7 tonnes
Processing (lima)	2 tons	2.2 tonnes
Fresh market (green and yellow)	200 crates	500 crates

Cultivars

Growers and processors are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Spacing and Seeding

Sow as shallow as soil moisture permits, usually 2.5–4 cm (1–1.5 in.) deep. Lima bean seed may be planted up to 5 cm (2 in.) deep, depending on soil moisture. Snap beans require a minimum soil temperature of 13°C (55°F) at the time of planting. Lima beans require slightly warmer planting conditions: 15°C (59°F).

Planting into cool soil conditions may result in reduced stands due to poor germination, low vigour and increased seed decay. Under good soil conditions, germination should occur within 6–10 days of planting.

The row spacings and seeding rates vary, depending on the bean type and harvest method. Because seed size varies greatly between cultivars, adjust the seeding rate according to seed count and the germination percentage. Increase the seeding rate slightly if seeding in cool soils to compensate for reduced stands. *Note:* Dark-coloured seeds have better cold soil emergence. See Table 9–4, *Snap and Lima Bean Spacing and Seeding Rates*, above.

Fertility

Nitrogen

Apply 30–40 kg N/ha (27–36 lb N/acre) prior to planting. This may be applied as a preplant broadcast application or banded through the planter, 5 cm below and 5 cm to the side of the seed. Side-dressing of nitrogen is only recommended if foliage shows nitrogen deficiency. Over-application of nitrogen will cause excess leaf growth, resulting in uneven maturity.

Table 9–4.
Snap and Lima Bean
Spacing and Seeding Rates

Crop	Row Spacing cm (in.)	In-Row Spacing cm (in.)	Recommended Plant Population (plants/acre)
Snap beans (hand harvest)	75–90 (30–36)	5–10 (2–4)	40,000
Snap beans (machine harvest)	60–75 (24–30)	5–10 (2–4)	50,000
Lima beans	60–75 (24–30)	10–20 (4–8)	35,000

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 16 mg P per L soil (ppm) or higher, lima and snap bean fields are unlikely to respond to additional phosphate applications. For soils testing lower than 16 mg P per L (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 121 mg K per L soil (ppm) or higher, snap and lima bean fields are unlikely to respond to additional potash applications. For soils testing lower than 121 mg K per L (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Because high rates of banded potassium can damage emerging seedlings, banded potassium should not exceed 60 kg potash/ha.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

BORON

Beans are very sensitive to boron toxicity and should not be grown the year after boron has been applied to previous crops in the field, such as brassica crops, celery or rutabaga.

MANGANESE

Manganese deficiency may be a problem on beans, especially on soils with pH values above 6.5. Correct the deficiency as

Table 9–5.
Snap Bean Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts per Million (ppm)				
Most recently mature trifoliate leaf	before bloom	3–4	0.25–0.45	2–3	0.8–1.5	0.2–0.45	0.4	25–200	20–100	20–40	15–40	5–10
	first bloom	3–4	0.25–0.45	2–3	0.8–1.5	0.26–0.45	0.21–0.4					
	full bloom	2.5–4	0.2–0.4	1.6–2.5	0.8–1.5	0.26–0.45	0.21–0.4					

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers.* 5th Edition. John Wiley & Sons, Inc. New York.

soon as detected with a foliar manganese spray. Soil application is not recommended for manganese because of the large amounts required. See the section *Manganese*, on page 19, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the range. Attempting to bring the nutrient analysis up to the higher end of the range could result in over-fertilization and may not be economical.

See Table 9–5, *Snap Bean Nutrient Sufficiency Ranges.* above. Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. For more information, see the section *Plant Analysis*, on page 3.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

For more information on the identification and management of these diseases, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. Also see Table 9–6, *Bean Seed Treatments*, below.

Table 9–6. Bean Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Insecticide and Fungicide Combinations				
Agrox B-2	diazinon + captan	80g per 25 kg seed	seed corn maggots, seed decay, damping off	**Seed box treatment** Do not use on seed already treated with an insecticide. Use within one month of treatment.
Agrox CD	diazinon + captan	50 g per 25 kg seed	seed corn maggots, seedling blight, seed rot.	**Seed box treatment** Do not use on seed already treated with an insecticide. Use only on seed previously treated with a fungicide.
Fungicide Only				
Apron XL LS	metalaxyl-M	20–40 mL per 100 kg seed	damping-off and root rot (high rate controls phytophthora root rot)	For use in commercial seed-treatment plants only. Does not control rhizoctonia.
Apron Maxx RTA	fludioxonil + metalaxyl-M	325 mL per 100 kg seed	fusarium, pythium and rhizoctonia seed decay, damping-off and seedling blight. Seed-borne anthracnose.	Ensure uniform coverage. 30-day plant-back interval to non registered crops.
Apron FL	metalaxyl	46–110 mL per 100 kg seed	pythium seed rot and seedling blight.	**For use in commercial seed-treatment plants only.** Do not feed to livestock for 4 weeks after planting.
Allegiance FL	metalaxyl	46–110 mL per 100 kg seed	pythium seed rot and seedling blight.	**For use in commercial seed-treatment plants only.** Do not feed to livestock for 4 weeks after planting.
Vitaflo	carbathiin + thiram	260 mL per 100 kg seed	rhizoctonia seed rot and seedling blight.	Also controls seed-borne anthracnose. Do not feed to livestock for 4 weeks after planting. Do not store treated seed.
Captan FL	captan	70 mL per 25 kg seed	seed decay, damping-off and root rot	
Thiram 75 WP	thiram	25–35 g per 25 kg seed	seed decay and damping-off	**Seed box treatment** Do not feed treated clippings to livestock.
Insecticide Only				
Cruiser 5 FS	thiamethoxam	50-83 mL per 100 kg seed	potato leafhopper, seedcorn maggot and wireworm	**For use on imported seed only.** Not for domestic commercial or on-farm seed treatment. Use high rate for wireworm. Use high rate where populations are expected to be high.

Table 9–7.
Bean
Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
BACTERIAL BLIGHT (HALO AND COMMON)						
inorganic (group M)	copper hydroxide	Parasol Flowable	2.3–3.1 L	0.9–1.2 L	1	Make first application when plants are 15 cm (6 in.) high.
GREY MOULD (BOTRYTIS), WHITE MOULD (SCLEROTINIA)[2]						
carboximide (group 7)	boscalid	Lance WDG	560–770 g	224–308 g	7	Spray at 20%–50% bloom with a second application 7 days later. Maximum 2 applications/yr. Use 420 g/ha (168 g/acre) for grey mould control. 4-hr re-entry interval.
dicarboximide (group 2)	vinclozolin	Ronilan EG	1.0–1.5 kg in min. 220 L water	0.4–0.6 kg in 20 gal water	14	Spray at first bloom with a second application 7 days later. Maximum 2 applications/yr.
	iprodione	Rovral	1.5 kg in min. 300 L water	0.6 kg in min. 27 gal water	15	Spray at 50% bloom. 12-hr re-entry. Aerial application permitted.
chlorophenyl (group 14)	dicloran	Botran 75 W	3.25 kg in 800 L water	1.3 kg in 70 gal water	2	Spray at first bloom. Do not feed treated foliage to livestock.
ANGULAR LEAFSPOT AND RUST						
QoI (group 11)	pyraclostrobin	Headline EC	400 mL	160 mL	7	Snap beans (angular leaf spot control). Maximum 2 applications/yr. 48-hr re-entry.
			400–600 mL	160–240 mL	7	**Lima beans (rust control).** Maximum 2 applications/yr. 48-hr re-entry.
PYTHIUM DAMPING-OFF, PHYTOPHTHORA ROOT ROT						
phenylamides (group 4)	metalaxyl-M	Ridomil Gold 480EC	300 mL[3]	120 mL[3]		**Snap beans only.** Make only 1 application/yr at planting.

[1] PHI = Pre-Harvest Interval

[2] For snap beans grown in fields recently affected by sclerotinia white mould.

[3] Based upon 2.3 mL per 100 m (328 ft) of row using a 20-cm (8-in.) spray band and a 76-cm (30-in.) row spacing.

WHITE MOULD (SCLEROTINIA)

Identification: Dark-green, water-soaked lesions develop on the pods, branches or stems during or after flowering. The lesions enlarge rapidly, encompassing the branches and stems, causing leaves to turn yellow and die. White, cottony fungal growth may develop on pods and stems.

Development: White mould overwinters in the soil as small, black (pea-sized) sclerotia. Bean plants are most susceptible during flowering and early pod development. Temperatures ranging from 20°C–25°C (68°F–77°F) and continuous leaf wetness (high humidity and/or heavy dews) favour sclerotinia white mould development. Overwintering sclerotia may survive for several years in the soil.

Thresholds: None established.

Management Notes: Practice a 3–4-year crop rotation away from susceptible crops (vine crops, edible beans, soybeans, carrots and lettuce). Reduced tillage may decrease the number of sclerotia present at the soil surface, helping to prevent germination. Excess nitrogen applications may result in an exceptionally dense canopy, resulting in restricted air movement and more favourable disease development conditions.

See Table 9–7, *Bean Disease Control Recommendations*, above. High humidity, heavy dews or wet weather during bloom may result in the need for a second spray.

BACTERIAL BLIGHTS (BROWN SPOT, COMMON BLIGHT, HALO BLIGHT)

Symptoms: The three bacterial blights are difficult to distinguish in the field. On leaf tissue, look for circular, brown, necrotic lesions, often surrounded by a yellow border. Pod lesions are usually slightly sunken and dark reddish-brown. The pods often become misshapen where the lesions develop.

Development: Common blight usually occurs during warm, humid conditions of 25°C–30°C (77°F–86°F). Halo blight prefers cooler temperatures in the 16°C–20°C (61°F–68°F) range.

Thresholds: None established.

Management Notes: Use only certified seed. The bacterial blight pathogens do not generally overwinter on crop residue in Ontario. Plants damaged by high winds or sand blasting are more susceptible to infection. See Table 9–7, *Bean Disease Control Recommendations*, on page 74. In order to be effective, copper fungicides must be applied preventatively.

VIRUSES (BEAN COMMON MOSAIC, BEAN YELLOW MOSAIC, CUCUMBER MOSAIC)

Symptoms: Leaves develop patches of light- and dark-green discolouration. They may also become puckered and twisted. Plants are often stunted, with poor seed set and misshapen pods. Bean yellow mosaic may also produce bright yellow spots on the leaf tissue.

Development: These viruses are spread by aphids and usually follow periods of high aphid activity.

Management Notes: Chemical aphid controls will not necessarily reduce the amount of viral diseases in the field. See the section *Viruses (General)*, on page 59. Bean common mosaic is also seed-borne. Buy certified, treated seed and select resistant varieties where possible. Several vegetable crop viruses overwinter in red clover and alfalfa fields. If possible, avoid planting beans near perennial forage crops.

Insects

SEEDCORN MAGGOTS, WIREWORMS, TARNISHED PLANT BUG, APHIDS

For identification and management information on these common vegetable insects affecting beans, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, Table 9–6, *Bean Seed Treatments*, on page 73, and Table 9–8, *Bean Insect Control Recommendations*, on page 76.

POTATO LEAFHOPPER

Identification: The adult leafhopper is yellow-green, wedge-shaped and approximately 3 mm long. Immature nymphs are smaller and wingless. When disturbed, leafhoppers quickly move forward or sideways. Both the adults and the nymphs feed on beans, causing leaf puckering and browning of the leaf margins (also known as "hopperburn"). Hopperburn is often confused with drought stress.

Period of Activity: Leafhoppers migrate to Ontario in early spring. Initial generations feed on alfalfa before moving into bean crops. Plants are most susceptible to feeding damage prior to bloom. Low levels of feeding on newly emerged seedlings can have a severe impact on yield. Leafhoppers are often found on the undersides of the leaves.

Thresholds:

Adults	seedling	2 per 33-cm (1-ft) row
	3rd trifoliate	5 per 33-cm (1-ft) row
Nymphs	any stage	10 per 100 leaves

Management Notes: See Table 9–8, *Bean Insect Control Recommendations*, on page 76, and Table 9–6, *Bean Seed Treatments*, on page 73. Where beans are planted in the vicinity of an alfalfa field, monitor the crop closely after the hay is cut.

EUROPEAN CORN BORER

Identification: Full-grown corn borer larvae are 2.5 cm (1 in.) in length. They are a greasy white (translucent) colour, with spots and a dark head. Eggs are shiny, white and laid in clusters of 30 that resemble fish scales. Corn borer larvae feed briefly on the leaves but soon begin tunnelling into the stems and pods. Since much of the pod damage is internal with only a small entry hole visible on the outside, grading-out infested pods is very difficult.

Period of Activity: Borers overwintering in corn stubble become active as soil temperatures consistantly exceed 10°C (50°F). Southwestern Ontario experiences two generations per year, while the rest of the province has only one. Beans are susceptible to damage from flowering through to harvest.

Thresholds: None established.

Table 9–8.
Bean
Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
LEAFHOPPERS, MEXICAN BEAN BEETLES, TARNISHED PLANT BUG, APHIDS						
pyrethroid (group 3)	lambda-cyhalothrin[2]	Matador 120 EC[2]	83 mL	33 mL	14	**Leafhoppers, tarnished plant bugs and aphids.** Maximum 3 applications/yr. 24-hr re-entry.
organophosphate (group 1B)	dimethoate[2]	Cygon 480[2]	0.7–1 L	0.28–0.4 L	7	Aerial application permitted. Maximum 3 applications/yr.
		Lagon 480[2]	0.7–1 L	0.28–0.4 L	7	**Snap beans only.** Aerial application permitted. Maximum 3 applications/yr.
	malathion	Malathion 500 E	1.5–2.75 L	0.6–1.1 L	3	Will not control tarnished plant bug.
	naled	Dibrom	1.1–2.2 L	0.44–0.88 L	4	**Aphid control only.** **Lima beans only.** Aerial application permitted. Do not apply when temperature is >32°C (90°F).
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	5	**Potato leafhopper and Mexican bean beetle.** Use low rate on young plants. Use high rate for leafhoppers.
chlorinated cyclodiene (group 2A)	endosulfan[2]	Thiodan 4 EC[2]	1.5–2.5 L	0.6–1 L	2	**Potato leafhopper and Mexican bean beetle.** Do not apply on lima beans. Also controls green cloverworm.
		Thionex 50 WP[2]	1.1–1.5 L	0.4–0.6 L	2	
CORN BORER						
pyrethroid (group 3)	lambda-cyhalothrin[2]	Matador 120 EC[2]	83 mL	33 mL	14	Apply before corn borer larvae tunnel into the stalk or pods. Maximum 3 applications/yr. 24-hr re-entry.
	permethrin	Pounce 384 EC	260 mL	104 mL	7	Aerial application permitted. Maximum 2 aerial applications/yr.
naturalyte (group 5)	spinosad	Success 480 SC	83 mL	33 mL	3	**Snap beans only.** Use only on small larvae and low infestations. Maximum 2 applications/yr. Maintain a spray pH of 6 or greater.
		Entrust 80 W	50 g	20 g	3	
biological (group 11)	*Bacillus thuringiensis*	Bioprotec CAF	2.8–4.0 L	1.1–1.6 L	1	**Snap beans only.** Maximum 4 applictions/yr. Allow 5–10 days between applications.
carbamate (group 1A)	methomyl	Lannate TNG	550 g	220 g	7	24 hr re-entry interval.
CUTWORMS						
pyrethroid (group 3)	lambda-cyhalothrin[2]	Matador 120 EC[2]	83 mL	33 mL	14	Apply in the late evening or at night. Maximum 3 applications/yr. 24-hr re-entry interval.
SLUGS						
inorganic	ferric phosphate	Sluggo	25–50 kg	10–20 kg	0	Apply to moist soils. Use higher rates on severe infestations.
SPIDER MITE						
diphenylethane (group 3)	dicofol[2]	Kelthane 50W[2]	1.0–1.25 kg	0.4–0.5 kg	7	Make only 1 application/yr. Use high rate on larger plants.

[1] PHI = Pre-Harvest Interval.

[2] Do not graze or feed treated foliage to livestock.

Management Notes: Where beans follow corn in rotation, consider disking the corn residue in the fall to reduce overwintering borer populations. Borers are most likely to be a pest in snap beans when other host plants are not available (early season, before corn is attractive, or late season, after the corn has dried down.) For control options, see Table 9–8, *Bean Insect Control Recommendations*, on page 76.

For more information, see the OMAFRA Factsheet, *European Corn Borer in Sweet Corn and Other Horticultural Crops*, Order No. 97-019.

MEXICAN BEAN BEETLE AND BEAN LEAF BEETLE

Identification: Both the adult and the larvae of these beetles are pests of snap bean in Ontario. Mexican bean beetle adults are coppery-red, oval and approximately 6 mm ($^{1}/_{4}$ in.) in length with 16 black spots on the wing casings. They resemble ladybugs. The larvae are yellow with rows of long, black-tipped spines along their backs.

Bean leaf beetle adults are 5 mm in length with four black spots on the wing covers. A small, black triangle is visible at the base of the head. The colour varies from yellow to tan or red. Bean leaf beetle larve complete their development in the soil, feeding on roots.

Period of Activity: Mexican bean beetle adults emerge from overwintering sites (grassy fencerows and wooded areas) in early May. Eggs are laid, and feeding continues for approximately 1 month. Mexican bean beetles complete one-to-two generations per year.

Bean leaf beetles complete only one generation. The adults emerge in late April and may be found feeding on early snap bean plantings. Egg-laying occurs until late June, with the larvae feeding on the roots for up to 30 days before the adults emerge.

Thresholds: Chemical controls may be required if leaf defoliation exceeds 20% prior to bloom and 10% during pod-fill. See Figure 9–1, *Defoliation Chart for Soybean Leaf-Feeding Insects*, right. Excessive defoliation from these beetles will result in early maturity and yield losses.

Management Notes: See Table 9–8, *Bean Insect Control Recommendations*, on page 76. Border sprays may be an effective way to control the beetles as they move out of the fencerow.

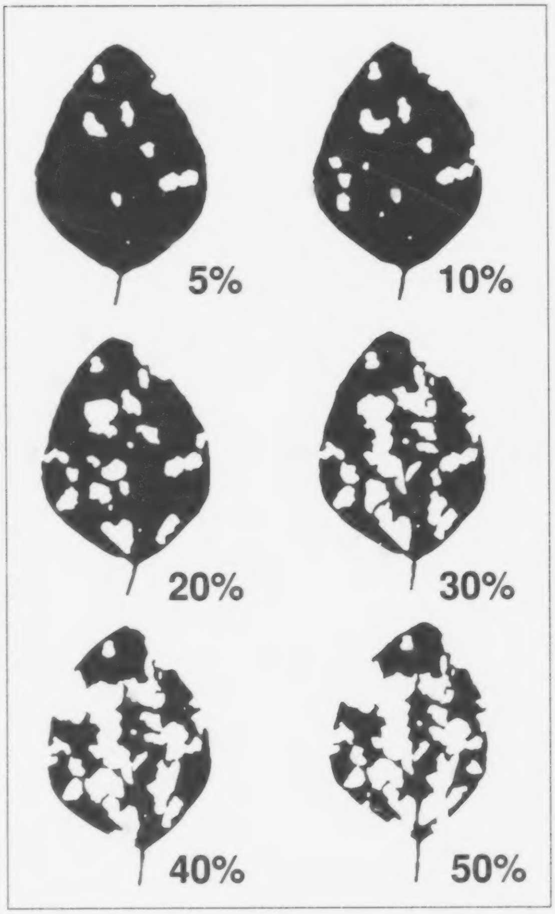

Figure 9–1.
Defoliation Chart for Soybean Leaf-Feeding Insects
Source: University of Illinois and Purdue University, 1982.

TWO-SPOTTED SPIDER MITES

Identification: The adult mite is approximately 0.5–1 mm in length and is barely visible to the naked eye. They are a translucent yellowish colour with two dark spots on the sides of their abdomen. Spider mites use sucking mouth parts to feed on individual cells. Injury first appears as yellowing or a bronzed, stippled effect. Severe feeding causes curling and drying of the leaves. Symptoms are often confused with drought stress. Mites are often found on the lower leaf surface, surrounded by a fine silk webbing.

Period of Activity: Spider mite activity is most common in hot, dry conditions. They often move into bean crops following wheat harvest.

Thresholds: Populations prior to pod fill are the greatest cause for concern. Spray if there are 4 or more mites per leaf or one severely damaged leaf per plant.

Management Notes: Heavy rain or overhead irrigation often reduces mite levels to below threshold. See Table 9–8, *Bean Insect Control Recommendations*, on page 76.

Physiological Disorders

Bronzing

Bronzing is a physiological disorder caused by high levels of atmospheric ozone associated with air pollution. A bronze-coloured stipple develops on the pods and the upper surface of the leaves. Pod and seed set are usually reduced, and the plants age prematurely. Dry beans and limas appear more sensitive than snap beans; cultivars within these types differ in susceptibility. Be careful not to confuse air pollution injury with spider mite feeding.

Storage

Store fresh-market snap beans at 7°C–10°C (45°F–50°F) and a relative humidity of 95%. Under good conditions, beans will store for 7–10 days. If possible, keep lima beans at slightly lower temperatures.

BEETS, TABLE

Production Requirements

Beets prefer a well-drained, loamy soil. They can also be grown successfully on well-drained muck soils. Emergence will be poor on heavy soils or those prone to crusting. A soil pH of 6.8–7.8 is ideal. Beets require 55–80 days from seeding to harvest for fresh market and 70–110 days for processing crops.

Beets are frost tolerant. The best colour and quality are obtained when they are grown during cool temperatures: 13°C–21°C (55°F–70°F). Heavy rains following a hot, dry period or extended periods of high temperature will cause poor colour.

Average Yields

Crop	per acre	per hectare
Fresh-market beets	400–600 50-lb bags	1,000–1,500 50-lb bags
Processing beets	15–20 tons	34–45 tonnes

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229. For beets grown for processing, the processor will determine the varieties to be grown.

Field Seeding and Spacing

For a continuous supply of beets for bunching, sow seed at 2-week intervals, from early April to the end of July. Early processing crops can also be seeded in early spring. For storage and late processing crops, sow about 10 weeks before late-fall harvesting. Seed will not germinate at temperatures lower than 4.5°C (40°F). The optimum germination temperature is from 10°C–29°C (50°F–84°F).

If necessary, thin plants 5–8 cm (2–3 in.) apart. No thinning is required when seeders are adjusted to ensure a stand of 32–40 plants/m of row (10–12 plants/ft of row).

	Metric	Imperial
Row spacing:	30–40 cm	12–16 in.
Rate:	7 kg/ha	6 lb/acre
Depth:	1.2–2.0 cm	½–¾ in.

Table 9–9.
Table Beet Nitrogen Recommendations

Soil	Actual N	
	kg/ha	lb/acre
Mineral Soils		
Preplant	65	58
Side-dress	45	40
Total	**110**	**98**
Muck Soil		
Preplant	40	36

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Broadcast and incorporate all the recommended preplant nitrogen along with the recommended potash and phosphate. On mineral soils, apply the remainder of the nitrogen as a side-dress application. See Table 9–9, *Table Beet Nitrogen Recommendations*, above.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, beets grown on both mineral and muck soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, beets grown on both mineral and muck soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, apply and incorporate them prior to planting.

Table 9–10.
Table Beets Nutrient Sufficiency Ranges

		N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
Plant Part	**Time of Sampling**	**Percent (%)**						**Parts per Million (ppm)**				
Leaf blades	5 weeks after seeding	3–5	0.25–0.4	2–6	1.5–2	0.25–1	0.6–0.8	40–200	30–200	15–30	30–80	5–10
	9 weeks after seeding	2.6–4	0.2–0.3	1.7–4	1.5–3	0.3–1	0.6–0.8	–	70–200	15–30	60–80	5–10

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers.* 5th Edition. John Wiley & Sons, Inc. New York.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

BORON

Boron deficiency shows up as a corky, dark discolouration of internal tissues. It is most likely to occur on high pH (alkaline) soils after prolonged hot, dry periods. See the section *Boron*, on page 18, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

MANGANESE

Deficient plants show marked yellowing between the leaf veins; the veins themselves remain green. To correct a deficiency, spray with manganese sulfate. See the section *Manganese*, on page 19, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical.

See Table 9–10, *Table Beets Nutrient Sufficiency Ranges*, above. Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing, or a sound soil fertility program. For more information, see the section *Plant Analysis*, on page 3.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information on these common vegetable diseases affecting table beets, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. Also see Table 9–11, *Table Beet Seed Treatments*, below.

CERCOSPORA LEAF SPOT

Identification: Look for numerous small, circular lesions with a dark-brown to purplish halo on the leaves. Small black dots may be seen with a magnifying lens in the centre of the lesions. The centres may turn grey and fall out, leaving a ragged appearance. This disease can lead to defoliation and reductions in yield. Leaf lesions reduce the marketability of fresh beets sold with tops.

Development: Cercospora is present from mid-July through early September. Air temperatures above 24°C (75°F) with extended periods of leaf wetness due to rain, heavy dews or fog are favourable for cercospora development.

Thresholds: None established. Monitor for the appearance of leaf lesions.

Management Notes: If monitoring indicates a need, apply fungicide as indicated in Table 9–12, *Table Beet Disease and Insect Control Recommendations*, on page 81.

POCKET ROT, ROOT ROT (RHIZOCTONIA)

Identification: Symptoms vary from cankers on lower petioles and crowns to root rot of beets.

Table 9–11.
Table Beet Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20–40 mL per 100 kg seed	damping-off	Export use only. For use in commercial seed-treatment plants only.
Thiram 75 WP	thiram	90 g per 25 kg seed	damping-off, seed decay	

Table 9–12.
Table Beet Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
CERCOSPORA LEAF SPOT						
inorganic (group M1)	copper sulfate	Copper 53 W	4.0 kg	1.6 kg	1	
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	225–336 g	3	Maximum 2 sequential applications. Maximum 3 applications. 72-hour re-entry (hand-thinning).
RHIZOCTONIA ROOT & CROWN ROT						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/100 m of row	1.2–1.8 mL/100 ft of row	40	One application/yr, applied in-furrow at planting or banded within 30 days of emergence.
CUTWORMS						
pyrethroid (group 3)	permethrin	Pounce 384 EC	180–390 mL	72–154 mL		Use higher rates on muck or dry soils or large larvae.
APHIDS						
organophosphate (group 1B)	dimethoate	Cygon 480	700 mL	280 mL	12	**Beet greens only.**
	diazinon	Diazinon 500 E	1.1 L	0.45 L	14	Control of aphids with diazinon has been inconsistent in many areas.
		DZN 600 EW	915 mL	370 mL	14	
	malathion	Malathion 25 W	2.25–5.5 kg	0.9–2.2 kg	7	Control of aphids with malathion has been inconsistent in many areas.
		Malathion 500 E	1.1–2.75 L	0.45–1.11 L	7	
LEAFHOPPERS						
organophosphate (group 1B)	dimethoate	Cygon 480	700 mL	280 mL	12	**Beet greens only.**

[1] PHI = Pre-harvest Interval.

Development: This disease is more severe when sustained wet conditions have occurred. It is most active at temperatures of 25°C–33°C (77°F–91°F).

Thresholds: None established.

Management Notes: Avoid throwing soil onto beet roots while cultivating. Rotate with grain crops. Management practices aimed to improve drainage and soil structure should reduce disease severity.

Insects

WIREWORMS, CUTWORMS, APHIDS

For identification and management information on these common vegetable insects affecting table beets, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–12, *Table Beet Disease and Insect Control Recommendations*, above.

LEAFMINERS

Identification: Look for the presence of tunnels or "mines" inside the leaves. Eggs are laid on the underside of leaves.

Development: Throughout the season.

Thresholds: None established. Scout for mines or for eggs on the underside of leaves.

Management Notes: Leafminer control is usually required only for bunching beets, where damage-free tops are required.

Nematode Control

To avoid damage from sugar-beet cyst nematode, do not plant beets following rhubarb, spinach, beets or cruciferous crops. Rotation to non-host crops for 4–5 years will significantly reduce populations of this nematode. See the section *Nematodes*, on page 63.

Harvest and Storage

Harvest of early plantings begins in mid-summer and can continue through fall frosts for late crops. Harvest must be completed before a hard freeze.

Mature, topped beets may be stored for 4–6 months at close to 0°C (32°F) and 98%–100% relative humidity. Do not allow the beets to freeze.

BRASSICA CROPS

BROCCOLI, BRUSSELS SPROUTS, CABBAGE, CAULIFLOWER, HORSERADISH, KALE, KOHLRABI, AND SPECIALTY VEGETABLES, INCLUDING CHINESE CABBAGE, CHINESE MUSTARD, BROCCOLI RAAB, COLLARDS, MIZUNA, MUSTARD GREENS, MUSTARD SPINACH AND RAPE GREENS

Production Requirements

Brassica crops are cool-season vegetables. They grow best in sandy loam soils at a pH of 6.5. They prefer moderate temperatures and can withstand mild frosts. Cauliflower is the most sensitive to adverse weather. Brassica crops have a relatively high moisture requirement. Even moderate drought stress at any time during the growing season may cause significant reductions in growth, yield or quality. Growth during dry periods may cause tipburn, bolting and/or buttoning.

Broccoli, Brussels sprouts, cabbage and cauliflower mature in 70–120 days. Most kale and kohlrabi mature in 50–55 days.

Average Yields

Crop	per acre	per hectare
Broccoli	260–320 cases (12, 14 or 18 bunches/case)	650–800 cases
Brussels sprouts	10,000 –12,000 lb	11,000–13,500 kg
Cabbage	650–1,000 cases (12 or 16 heads/case)	1,500–2,500 cases
Cauliflower	450–700 cases (6, 9, 12 or 16 heads/case)	1,000–2,000 cases
Horseradish	6,750–10,800 lb	7,500–12,000 kg
Kale	40,000 lb	45,000 kg
Kohlrabi	12,000–16,000 lb	13,500–18,000 kg

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under Ontario growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding, Spacing and Establishment

Brassica seeds will germinate at temperatures as low as 4°C (39°F). However, they develop best at temperatures between 21°C–24°C (70°F–75°F). Direct seeding in the field is possible for late summer and fall crops of cabbage, cauliflower, broccoli and Brussels sprouts. However, this practice is not widely used in Ontario. Consider establishing transplants from plug trays as a method of promoting uniform size and maturity.

Despite the higher initial cost of plug plants, the benefits include better seed use efficiency and reduced transplanting and thinning costs. Plug-raised plants also establish quickly and provide a more uniform and vigorous stand compared to bare-root transplants. See Table 9–13, *Brassica Crop Spacing and Seeding Rates*, on page 83.

Fertility

Starter Solution

If no insecticide is being added to the planting water, use a starter solution high in nitrogen such as 20-20-20 at 1 kg /200 L and apply 0.2–0.3 L per plant. Under high temperatures or in dry sandy soils, use half the recommended rate (in the same volume of water) to reduce the risk of crop injury under these growing conditions.

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Broadcast and incorporate the recommended preplant nitrogen with all the required potash and potassium. Side-dress the remaining nitrogen approximately 3 weeks after field setting. See Table 9–14, *Brassica Crop Nitrogen Recommendations*, on page 83.

Phosphorus

Soil tests are required to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, brassica crops are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Table 9–13.
Brassica Crop Spacing and Seeding Rates

Crop	Row Spacing[1]		In-Row Spacing		Seed Required	
	cm	in.	cm	in.	g/ha	g/acre
Broccoli[2], early cabbage	60–75	24–30	30–45	12–18	300–350	120–140
Late cabbage, cauliflower and Brussels sprouts[3]	75–90	30–35	45–60	18–24	300–350	120–140
Horseradish	75–90	30–35	40–60	16–24	300–350	120–140
Kale[4]	70–80	28–32	thinned to 30 cm	thinned to 12 in.	300–350	120–140
Kohlrabi[4]	70–80	28–32	thinned to 10 cm	thinned to 4 in.	300–350	120–140
Nappa cabbage[4]	45–60	18–24	25–30	10–12	100–220	40–88
Bok choy[4]	45	18	15–20	6–8	336	135
Chinese broccoli[4]	30–45	12–18	thinned to 5–10 cm	thinned to 2–4 in.	900	360

[1] New, more compact hybrids may be grown at closer spacings than the traditional cultivars.

[2] Increased plant spacings are required for broccoli crops that will be harvested during the hot, humid weather of late August to early September.

[3] Close square spacing of 60 x 60 cm (24 x 24 in.) or even 53 x 53 cm (21 x 21 in.) is required to improve the uniformity of Brussels sprouts that are grown for once-over harvesting and/or where smaller sprouts are required for freezing.

[4] Direct seeded.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, brassica crops are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, they should be broadcast and incorporated prior to planting.

Table 9–14.
Brassica Crop Nitrogen Recommendations

Soil Type	Actual N kg/ha (lb/acre)		
	Broccoli, Cauliflower, Brussels Sprouts	Cabbage	Horseradish, Kale, Kohlrabi
Mineral Soils[1]			
Preplant	100 (89)	130 (116)	80 (71)
Side-dress[2]	30 (27)	40 (36)	30 (27)
Total	**130 (116)**	**170 (151)**	**110 (98)**
Muck Soils			
Preplant	70 (62)	100 (89)	70 (62)
1st side-dress	30 (27)	30 (27)	30 (27)
2nd side-dress	30 (27)	30 (27)	30 (27)
Total	**130 (116)**	**160 (142)**	**130 (116)**

[1] If rainfall is excessive, an additional 40 kg of nitrogen/ha may be side-dressed on sandy soils.

[2] 3 weeks after field setting.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

BORON DEFICIENCY

Boron deficiency has been shown to cause hollow stem in broccoli, but not all hollow stem is caused by boron deficiency. Use caution when applying boron. This nutrient can build to toxic levels quite quickly, harming rotational crops. See the section *Boron*, on page 18, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

MOLYBDENUM DEFICIENCY

Molybdenum deficiency causes whiptail in cauliflower, broccoli and Brussels sprouts. Molybdenum can be applied in the transplanting water at the rate of 30–40 g of sodium molybdate per 100 L of water, each plant receiving 0.3 L of this solution. See the section *Molybdenum*, on page 20, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical.

Table 9–15.
Brassica Crop Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts per Million (ppm)				
Broccoli												
Most recently mature leaf	heading	3–4.5	0.3–0.5	1.5–4	1.2–2.5	0.23–0.4	–	40–300	25–150	45–95	30–50	5–10
Brussels sprouts												
Most recently mature leaf	at early sprouts	2.2–5	0.2–0.6	2.4–3.5	0.4–2	0.2–0.4	0.2–0.8	50–150	20–200	20–80	30–70	5–10
Cabbage												
Most recently mature leaf	5 weeks after transplanting	3.2–6	0.3–0.6	2.8–5	1.1–2	0.25–0.6	0.3	30–60	20–40	30–50	20–40	3–7
	8 weeks after transplanting	3–6	0.3–0.6	2–4	1.5–2	0.25–0.6	0.3	30–60	20–40	30–50	20–40	3–7
Wrapper leaf	heads half grown	3–4	0.3–0.5	2.3–4	1.5–2	0.25–0.45	0.3	20–40	20–40	20–30	30–50	4–8
	at harvest	1.8–3	0.26–0.4	1.5–3	1.5–2	0.25–0.45	0.3	20–40	20–40	20–30	30–50	4–8
Cauliflower												
Most recently mature leaf	buttoning	3–5	0.4–0.7	2–4	0.8–2	0.25–0.6	0.6–1	30–60	30–80	30–50	30–50	5–10
	heading	2.2–4	0.3–0.7	1.5–3	1–2	0.25–0.6	–	30–60	50–80	30–50	30–50	5–10
Chinese cabbage (heading)												
Oldest undamaged leaf	8-leaf stage	4.5–5	0.5–0.6	7.5–8.5	4.5–5	0.35–0.45	–	–	14–20	30–50	15–25	5–10
	at maturity	3.5–4	0.3–0.6	3–6.5	3.7–6	0.4–0.5	–	–	13–19	20–40	30–50	4–6

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*. 5th Edition. John Wiley & Sons, Inc. New York.

See Table 9–15, *Brassica Crop Nutrient Sufficiency Ranges*, above. Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing, or a sound soil fertility program.

For more information, see the section *Plant Analysis*, on page 3.

Integrated Pest Management

> See OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario,* for a comprehensive guide to insect and disease management in brassica crops.

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information, see Chapter 8, page 59.

To prevent damping-off, seedling blight and seed decay, apply Thiram 75 WP at a rate of 90 g per 25 kg or seed (not for use on kale, horseradish or kohlrabi or any of the specialty vegetables).

To manage damping-off and root rots in greenhouse transplants, see Table 9–16, *Brassica Crop Disease Control Recommendations*, on page 85.

DOWNY MILDEW

Identification: Symptoms appear as yellow spots on the upper leaf surface with corresponding greyish-white fungal growths on the underside. Infected cauliflower curds develop dark-grey spots. When the curds are cut open, a grey streaking is evident beneath the florets. In broccoli, grey streaking occurs beneath the beads. This discolouration leads back to the main stem. Cabbage heads develop numerous black spots.

Development: Infection can occur at any growth stage. Cool temperatures of 10°C–15°C (50°F–59°F) and prolonged periods of leaf wetness, dew or fog are required. This fungus overwinters in seed and on infected plants. Downy mildew fungi survive for at least 1 year in the soil and 2 years in infected seed.

Thresholds: None established.

Management Notes: Plant into a well-drained soil. Avoid excessive use of overhead irrigation. Practice a 2-year rotation with non-host crops. Resistant broccoli varieties are available.

If weather conditions favour disease development, apply one of the preventative fungicides listed in Table 9–16, *Brassica Crop Disease Control Recommendations*, on page 85.

Table 9–16.
Brassica Crop Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
GREENHOUSE TRANSPLANT DISEASE CONTROL (DAMPING-OFF AND ROOT ROT)						
phthalamide (group M4)	captan	Maestro 80 DF	1.25 kg/1,000 L of water. Apply 50–85 L of solution per 100 m² (1076 ft²).			Soil drench treatment. 48-hr re-entry.
		Supra Captan 80 WDG	1.25 kg/1,000 L of water. Apply 50–85 L of solution per 100 m² (1076 ft²).			Soil drench treatment. 48-hr re-entry.
dithiocarbamate (group M2)	oxine benzoate	No-Damp	10 mL/L of water			**Damping off.** Soil treatment.
DOWNY MILDEW, ALTERNARIA						
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.5–4.8 L	1–1.9 L	7	Not on horseradish, kale or kohlrabi.
phosphonate (group 33)	fosetyl-al	Aliette WDG	2.25–3.12 kg	0.9–1.25 kg	7	**Downy mildew only. Broccoli and bok choy only.** Maximum 5 applications/yr. 12-hr re-entry.
inorganic (group M1)	copper sulphate[2]	Copper 53 W[2]	4.0 kg	1.6 kg	1	**Broccoli, cabbage, cauliflower and Brussels sprouts only.**
dithiocarbamate (group M3)	zineb	Zineb 80 W	1.1–3.3 kg	0.44–1.3 kg	7	Not on horseradish, kale or kohlrabi.
dicarboximide (group 2)	iprodione	Rovral	3 kg	1.2 kg	7	**Alternaria only.** Storage cabbage.[3] 12-hr re-entry.
					5	**Alternaria only.** Cauliflower.[3] 12-hr re-entry.
QoI (group 11)	pyraclostrobin	Cabrio EG	0.56–1.1 kg	224–440 g	3	**Alternaria & cercospora control.** **Horseradish only.** Maximum 3 applications/yr. Apply no more than 2 sequential applications. 3-day re-entry (hand-thinning).
POWDERY MILDEW						
phenylpyrroles + anilino-pyramidines (group 12 + 9)	cyprodinil + fludioxonil	Switch 62.5 WG	775–975 g	310–390 g	7	**Mustard/turnip greens and cabbage only.** Maximum 3 applications/yr. Do not make more than 2 sequential applications. Use high rate for heavy disesase pressure.
RHIZOCTONIA						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 ml/100 m row		40	**Horseradish only.** One application/yr; applied in-furrow at planting or banded soon after emergence.
CLUBROOT (TRANSPLANT TREATMENT)[4]						
chlorophenyl (group 14)	quintozene	Quintozene 75 WP	250–270 g per 100 L water Minimum 200 mL per plant.			Provide good agitation during application.

[1] PHI = Pre-Harvest Interval.

[2] Fixed copper may be phytotoxic to cauliflower.

[3] Apply Rovral on storage cabbage 7–14 days prior to harvest and on cauliflower 1–2 days prior to tying.

[4] Chemical control of clubroot is inconsistent.

FUSARIUM WILT (CABBAGE YELLOWS)

Identification: Infected seedlings turn yellow and die within 2–4 weeks. The lower leaves are affected first. The yellowing is often more intense on one side of the plant.

Development: Fusarium wilt is soil-borne. Plants may be affected at any time during growth. It enters the plant through young rootlets or through wounds in older roots. Fusarium wilt is a warm-weather disease and will not develop below 16°C (61°F) or above 32°C (90°F).

Management Notes: Use certified, disease-free seed and resistant cultivars (if available). Potassium deficiency may further aggravate this disease.

CLUBROOT

Identification: The first noticeable symptom of clubroot is the wilting, stunting and yellowing of plants in patches in the field. When the plants are pulled, a characteristic "clubbing" of the root tissue is evident. Severely distorted roots have difficulty absorbing water and minerals from the soil.

Development: Clubroot is a soil-borne disease. It affects all members of the crucifer family. Clubroot is present in the soil in most areas of the province. Once in a field, the resting spores persist for many years.

Management Notes: Control cruciferous weeds and rotate with non-crucifer crops. Maintain a soil pH of 7.2 or higher. Clubroot spores need free water to move in the soil. Plant into well-drained soils. Muck soils are at a high risk of clubroot infection. Grow only short-season (less than 6 weeks) crucifer crops on high-risk soils. See Table 9–16, *Brassica Crop Disease Control Recommendations*, on page 85.

BLACK ROT

Identification: V–shaped, yellow lesions develop along the leaf margins. As the lesions expand, the tissue turns brown, and the small veins become blackened.

Development: Black rot is spread rapidly during warm, humid weather. Once in the soil, the bacteria are spread by splashing rain and wind. Bacteria enter plants through wounds or natural openings at the leaf margins called "hydathodes."

Management Notes: Use certified, disease-free seed and/or hot-water-treated seed. Discard all diseased or unhealthy transplants before planting. Follow a 2–3-year crop rotation to non-crucifers and control all cruciferous weeds.

ALTERNARIA (BLACK LEAF SPOT)

Identification: Small, yellowish lesions develop on older leaves. As the spots expand, they resemble a "target" with concentric light and dark areas. On cauliflower and broccoli, black, sunken spots develop on individual florets. Infections on cabbage heads range in size from pinpoint to several centimetres in diameter.

Development: Alternaria is seed-borne. It also survives on many cruciferous weeds. It is spread by wind throughout the summer season. Cool, humid conditions favour black spot development.

Thresholds: None established.

Management Notes: Adequate air circulation will reduce humid conditions in the canopy. Ensure that cabbage heads are free of alternaria before going into storage. If this disease is present in the field, protect the plants with a fungicide prior to harvest. See Table 9–16, *Brassica Crop Disease Control Recommendations*, on page 85.

WHITE LEAF SPOT

Identification: Infected leaves exhibit scattered, circular, white-to-tan spots contained by leaf veins. These spots become white and papery, enlarging as the disease develops. Heavily infected plants may show severe spotting, with some defoliation. On waxy-leafed crucifer species, the lesions take on a branching shape.

Development: White spot persists from season to season on leaf litter. Cool temperatures from 12°C–18°C (54°F–64°F), rainfall and long periods of humidity are conducive to disease development. Spores can be spread by wind, splashing rain and irrigation. The disease does not spread in warm weather.

BACTERIAL SOFT ROT

Identification: Infected leaf or head tissue often takes on a tan colour, becoming moist and mushy and developing a foul odour.

Development: Soft rot spreads rapidly in warm, humid conditions. Insect damage may predispose plants to soft-rot infection.

Management Notes: Plant into well-drained soils and maximize air flow through the plant canopy. Avoid overhead irrigation once the disease has been diagnosed in a field. Rotate with less-susceptible crops (cereals or corn) and control chewing insects. In storage, temperatures below 4°C (39°F) inhibit the development of new infections. Practice good storage sanitation (see the section *Storage Sanitation*, on page 50).

BROWN HEART OR HOLLOW STEM

Some, although not all, hollow stem in broccoli is caused by boron deficiency. It may also be caused by fluctuations in growth due to heat or moisture stress. See the section *Boron*, on page 18, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

WHIPTAIL

Whiptail in cauliflower, broccoli and Brussels sprouts is caused by molybdenum deficiency. See the section *Molybdenum*, on page 20, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Table 9–17.
Brassica Crop
Cabbage Maggot Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate	PHI[1]	Notes
Planting-Water Treatment					
organophosphate (group 1B)	chlorpyrifos	Lorsban 50 W	65 g/200 L of water Apply 200 mL/plant.	32	**Cabbage only.** Do not use with starter fertilizers. 24-hr re-entry. 10 days for cauliflower.
Treatment After Planting					
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E[2]	210 mL/130 L of water per 1,000-m row	32	**Cabbage, cauliflower, broccoli, Brussels sprouts, Chinese cabbage and pak choy only.** Maximum 2 applications/yr (3 on Brussels sprouts). 24-hr re-entry. 10 days for cauliflower.
				32	**Asian-type radish (lo bok, daikon, moo).** 24-hr re-entry.
			150 ml/1,000 m of row	21	**Chinese broccoli.** Apply 5–7 days after seeding. 24-hr re-entry.
		Pyrinex 480 EC[2]	150 ml/1,000 m of row	21	**Chinese broccoli.** Apply 5–7 days after seeding. 24-hr re-entry.
			210 mL/130 L of water per 1,000-m row	32	**Asian-type radish (lo bok, daikon, moo).** 24-hr re-entry. 10 days for cauliflower.
		Lorsban 15 G	0.6–1.0 kg per 1,000-m row	32	**Direct-seeded cabbage, cauliflower, broccoli, Brussels sprouts only.** 24-hr re-entry. 10 days for cauliflower.
		Pyrifos 15 G			

[1] PHI = Pre-Harvest Interval.

[2] Apply in a 10-cm (4-in.) band on each side of the plant 3 days after transplanting or 7–10 days after direct seeding.

For further information on brassica crop diseases, see the following OMAFRA Factsheets:

- *Fungal Diseases of Cruciferous Crops,* Order No. 85-043
- *Bacterial Diseases of Cruciferous Crops,* Order No. 86-046
- *Black Rots of Crucifer Crops,* Order No. 02-025

Insects

APHIDS, CUTWORMS, SLUGS, TARNISHED PLANT BUG

For identification and management information on these common vegetable insects affecting brassica crops, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. See also Table 9–18, *Brassica Crop Aphid, Swede Midge and Pea Leafminer Control Recommendations*, on page 88, and Table 9–19, *Brassica Crop Flea Beetles, Thrips, Cutworms and Slug Control Recommendations*, on page 89.

CABBAGE MAGGOT

Identification: The cabbage maggot adult is a grey fly, approximately half the size of the common housefly. The female lays eggs in the soil at the base or near seedlings. The small (1-mm) white eggs look like tiny grains of rice. The larvae are small (7 mm or 1/4 in.), legless and white. The maggots tunnel and feed along the roots of crucifers. These wounds act as points of entry for soft rot bacteria.

Period of Activity: There are three periods of egg-laying throughout the season. The first generation is the most active and most damaging. It occurs from mid-May through June (flowering of yellow rocket). A second occurs in mid-July (flowering of day lilies) and a third in late August (flowering of goldenrod). These dates are only approximate, and activity varies, depending on regional temperatures and differences in soil type.

Thresholds: Cabbage root maggot management is primarily preventative. A Growing Degree Day (GDD) model has been developed for cabbage maggot. Using a base of 6°C, first generation adults are expected between 314 and 398 GDD. Second generation adults are expected between 847 and 960 GDD. Third generation adults are expected between 1446 and 1604 GDD. For more information, see the section *Growing Degree Days*, on page 32.

Management Notes: See Table 9–17, *Brassica Crop Cabbage Maggot Control Recommendations*, above. Later plantings are less likely to require protection.

Caution

- Do not use emulsifiable formulations in the planting water.
- Do not add fertilizer to planting water containing an insecticide unless recommended by the manufacturer or until experience has proven the mixture to be safe.

Table 9–18.
Brassica Crop
Aphid, Swede Midge and Pea Leafminer Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
SWEDE MIDGE						
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	83 mL	33.2 mL	1	**Cabbage.** Maximum 3 applications/yr. Allow 7 days between applications. 24-hr re-entry.
					3	**Broccoli, Brussels sprouts, cauliflower.** Maximum 3 applications/yr. Allow 7 days between applications. 24-hr re-entry.
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	34.4 g	7	**See the label for a complete list of all brassica crops, including specialty brassicas.** Maximum 5 applications/yr. Alternate sprays with other insecticide families. 12-hr re-entry.
APHIDS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	22.4–34.4 g	7	**See the label for a complete list of all brassica crops, including specialty brassicas.** Maximum 5 applications/yr. Alternate sprays with other insecticide families. 12-hr re-entry.
	imidacloprid	Admire 240 F	730 mL	292 mL	21	Side-Dress Application Inject to a depth of 2.5 cm, 5–10 cm to the side of each row. Maximum 1 application/yr. 24-hr re-entry.
			200 mL	80 mL	7	Foliar Application Do not make a foliar application following a soil application. Maximum 2 applications/yr. 24-hr re-entry.
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	28	**Not on broccoli, kale, kohlrabi, horseradish.** Maximum of 4 applications/yr.
	dimethoate	Cygon 480	0.7–1.0 L	0.28–0.4 L	4	Cauliflower, broccoli.
					7	Kale. Low rate only.
					21	Brussels sprouts. Use low rate on Brussels sprouts.
			0.6–1.0L	0.24–0.4 L	7	Chinese broccoli, Chinese cabbage, bok choy.
		Lagon 480 E	0.7–1.0 L	0.28–0.4 L	4	Broccoli and cauliflower.
					21	Brussels sprouts.
			0.6–1.0 L	0.24–0.4 L	7	Chinese broccoli. Maximum 3 applications/yr.
	methamidophos	Monitor 480	1.1–2.25 L	0.4–0.9 L	7	Cabbage, cauliflower. 48-hr re-entry.
					14	Broccoli, Brussels sprouts. 48-hr re-entry.
	naled	Dibrom	1.1 L	0.4 L	4	Broccoli, Brussels sprouts, cabbage, cauliflower and kale.
			1.1–1.65 L	0.44–0.66 L	4	Mustard greens. Maximum 3 applications/yr.
PEA LEAFMINER						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	34.4 g	7	**See the label for a complete list of all brassica crops, including specialty brassicas.** Maximum 5 applications/yr. Alternate sprays with other insecticide families. 12-hr re-entry.
chitin synthesis inhibitor (group 17)	cyromazine	Citation 75 WP	188 g in 200 L water	75 g in 20 gal water	7	**Leafy brassica greens only.** Maximum 5 applications/yr. 12-hr re-entry interval.

[1] PHI = Pre-Harvest Interval.

Table 9–19.
Brassica Crop
Flea Beetles, Thrips, Cutworms and Slug Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
FLEA BEETLES						
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	42 mL	17 mL	1	**Cabbage**. 24-hr re-entry. Maximum 3 applications/yr.
					3	**Broccoli, cauliflower, Brussels sprouts.** 24-hr re-entry. Maximum 3 applications/yr.
	cypermethrin[2]	Ripcord 400 EC[2]	87.5–125 mL	35–50 mL	3	**Cabbage, cauliflower, broccoli and Brussels sprouts.** Maximum 3 applications/yr.
	deltamethrin	Decis 5 EC	150–200 mL	60–80 mL	3	**Use on cabbage only.**
	permethrin	Pounce 384 EC	90–180 mL	36–72 mL	2	Horseradish.
					3	Cabbage, cauliflower, Brussels sprouts.
					7	Broccoli.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	1.5–2.0 L	0.6–0.8 L	7	Cabbage, cauliflower, broccoli and Brussels sprouts. Maximum 3 applications/yr.
		Thionex 50WP	1.1–1.75 kg	0.4–0.7 kg	7	
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	3	Cabbage and cauliflower.
					5	Broccoli, kohlrabi and Brussels sprouts.
					7	Horseradish.
					21	Kale, Chinese cabbage and mustard greens.
THRIPS						
pyrethroid (group 3)	cypermethrin[2]	Ripcord 400 EC[2]	87.5–125 mL	35–50 mL	3	**Cabbage, cauliflower, broccoli, Brussels sprouts only.** Maximum 3 applications/yr.
CUTWORMS						
pyrethroid (group 3)	cypermethrin[2]	Ripcord 400 EC[2]	175 mL	70 mL	14	**Cabbage, cauliflower, broccoli and Brussels sprouts.** Do not disturb soil for 5 days after application.
	permethrin	Pounce 384 EC	180–390 mL	72–155 mL	3	**Brussels sprouts, cabbage, cauliflower.** Use high rate on dry soils or large larvae. Apply up to 5-leaf stage. Do not disturb ground for 5 days following application.
					7	**Broccoli.** Use high rate on dry soils or large larvae. Apply up to 5-leaf stage. Do not disturb ground for 5 days following application.
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–1 L	32	**Cabbage, cauliflower, broccoli, Brussels sprout only.** Apply at 2–5-leaf stage. 24-hr re-entry (10 days for cauliflower).
		Pyrinex 480 EC	1.2–2.4 L	0.5–1 L	32	
SLUGS						
inorganic	ferric phosphate	Sluggo	25–50 kg	10–20 kg	0	Use high rates on heavy infestations, or after heavy rains.
carbamate (group 1A)	methomyl	Lannate TNG	775 g	310 g	30	**Brussels sprouts only.** 24-hr re-entry.

[1] PHI = Pre-Harvest Interval.

[2] Do not use on muck soils.

FLEA BEETLES

Identification: Flea beetles are small (2–3 mm), shiny black beetles. Adults are active and jump when disturbed. Feeding damage consists of numerous "shot-holes," 1–5 mm in diameter. At the seedling stage, flea beetle feeding can kill the plant.

Period of Activity: Adult flea beetles overwinter in leaf litter. They emerge and begin feeding on young plants in mid-May. Eggs are deposited near the roots of host plants throughout the spring and early summer. Larvae develop on the roots. In late July, adults emerge from the soil, feed and then seek hibernation sites in the fall.

Thresholds: Up to the 6-leaf stage, plants can tolerate no more than 1 flea beetle per plant. After this stage, feeding will not interfere with plant growth. Feeding damage at later stages may have an impact on marketability and crop quality.

Management Notes: Early plantings may be protected with row covers. Transplants are less susceptible to damage than direct-seeded crops. Flea beetles can spread black rot disease. Beetles tend to prefer specialty crucifers over traditional brassica crops. Trap crops, such as Indian mustard, have worked well in traditional crucifers. See Table 9–19, *Brassica Crop Flea Beetles, Thrips, Cutworms and Slug Control Recommendations*, on page 89.

THRIPS

Identification: Thrips are small (<3-mm), soft-bodied insects. They are cream-to-light-brown in colour. Thrips have sucking-rasping mouth parts and cause tissue damage when they feed on the leaves. The plant responds by forming scar tissue at the feeding site, giving the leaf a rough, rusty, warty appearance. Thrips damage can occur on all brassica crops. However, cabbage appears to be the most susceptible.

Period of Activity: Thrips overwinter on grasses (especially winter wheat) and alfalfa. They migrate into brassica crop fields as the weedy roadsides dry down and the winter wheat and alfalfa are harvested.

Thresholds: None established. If field monitoring indicates a need, start spraying for thrips once cupping of cabbage occurs.

Management Notes: Cabbage varieties vary in their susceptibility to thrips. Late plantings often suffer less damage than earlier ones. Harvest cabbage at the proper maturity; over-mature cabbage is a prime target for thrips. Control of thrips during head development is very challenging.

See Table 9–19, *Brassica Crop Flea Beetles, Thrips, Cutworms and Slug Control Recommendations*, on page 89.

IMPORTED CABBAGEWORM, CABBAGE LOOPER, DIAMONDBACK MOTH CATERPILLAR

Identification: Imported cabbageworm (ICW) caterpillars are leafy green and velvety in appearance. They have a pale yellow stripe down the centre of their back. The cabbage looper (CL) caterpillar is similar in size, smooth and pale green, with a thin white line along each side and two faint lines down the middle of the back. The cabbage looper moves like an "inchworm." Both the ICW and the CL chew large ragged holes in the leaves.

Diamondback moth larvae are much smaller than the other two species. When disturbed, they wiggle frantically, attach a silken thread to the leaf and dangle over the edge. Diamondback moth larvae chew through the inner-leaf layers, leaving the waxy epidermis, creating a "window-pane."

Period of Activity: Infestations of the ICW and DBM begin very early in the season. There is a possibility that the diamondback moth is overwintering in some areas along Lake Ontario and Lake Erie. Cabbage looper do not usually appear until mid-July. However, they have been found earlier in the southwestern municipalities of Chatham-Kent and Essex.

Thresholds: Using the Cabbage Looper Equivalent (CLE) method, thresholds are 0.3 for cabbage and 0.2–0.3 for cauliflower and broccoli.

Using the Percentage Infestation Method, thresholds are:

Cabbage	before head fill	20%–30%
	after	10%–15%
Cauliflower & broccoli	before head fill	20%–30%
	after	5%–10%

For more information on the calculation of these thresholds, see OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario.*

Management Notes: Insecticides are less effective against large larvae. Begin application of insecticides when young larvae are found and continue on a 5–10-day schedule, or as necessary for adequate protection of the crop. Scouting is an excellent way to assess the population of brassica-crop caterpillars.

See Table 9–20, *Brassica Crop Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar Control Recommendations*, on page 91. Diamondback moth develops resistance very quickly. To limit the development of resistance, always alternate between chemical families. Use pyrethroid insecticides during the fall, as they are more effective under cool conditions.

Table 9–20.
Brassica Crop
Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
biologicals (group 11)	*Bacillus thuringiensis*	Dipel 2XDF	55–550 g	22–220 g	0	**See the label for a complete list of all brassica crops, including specialty brassicas.** Use 275–550 g/ha (110–220 g/acre) for loopers.
			275–550 g	110–220 g	0	Mustard greens only.
		Thuricide HPC	2.0–4.25 L	0.8–1.7 L	0	**See the label for a complete list of all brassica crops, including specialty brassicas.** Use higher rates for looper control, heavy infestations or when foliage is dense.
		Bioprotec CAF	1.4–2.8 L	0.5–1.1 L	0	
naturalyte (group 5)	spinosad	Success 480 SC	182 mL	72.8 mL	3	**See the label for a complete list of all brassica crops, including specialty brassicas.** Mamimum 3 applications/yr. 3-day re-entry interval for tying and harvest activities. Maintain a spray pH of 6 or higher.
		Entrust 80 W	109 g	44 g	3	
pyrethroid[2] (group 3)	deltamethrin	Decis 5 EC	150–200 mL	60–80 mL	1	**Brussels sprouts only.**
					3	**Cabbage, cauliflower, broccoli only.**
	cyhalothrin-lambda	Matador 120 EC	42 mL	17 mL	1	Cabbage. Imported cabbageworm and diamondback moth larvae. 24-hr re-entry.
					3	Broccoli, cauliflower, Brussels sprouts. Imported cabbageworm and diamondback moth larvae. 24-hr re-entry.
			83 mL	33 mL	1	Cabbage. Cabbage looper. 24-re-entry.
					3	Broccoli, cauliflower, Brussels sprouts. Cabbage looper. 24-hr re-entry.
	cypermethrin[3]	Ripcord 400 EC[3]	87.5–125 mL	35–50 mL	3	**Cabbage, cauliflower, broccoli, Brussels sprouts only.**
	permethrin	Pounce 384 EC	90–180 mL	36–72 mL	3	Cabbage, cauliflower, Brussels sprouts, pak choy and Chinese cabbage.
					7	Broccoli.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1–1.75 kg	0.4–0.7 kg	7	Cabbage, cauliflower, broccoli and Brussels sprouts. Use high rate on loopers.
		Thiodan 4 EC	1.5–2.0 L	0.6–0.8 L	7	
carbamate[2] (group 1A)	methomyl[2]	Lannate TNG[2]	270–540 g	108–216 g	1	Cabbage. 24-hr re-entry.
					7	Cauliflower, broccoli, Brussels sprouts. 24-hr re-entry.
	carbaryl	Sevin XLR	2.5–5.25 L	1–2.1 L	3	Cabbage and cauliflower.
					5	Broccoli, Brussels sprouts and kohlrabi.
					7	Horseradish.
					21	Kale, Chinese cabbage and mustard greens.
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.4 kg	28	Maximum 4 applications/yr. Not on broccoli, kale, kohlrabi, horseradish.
	naled	Dibrom EC	1.1–2.2 L	0.4–0.9 L	4	Broccoli, Brussels sprouts, cabbage, cauliflower, kale and mustard greens. High rate for loopers only
	methamidophos	Monitor 480	1.1–2.25 L	0.4–0.9 L	21	For cabbage, cauliflower. 48-hr re-entry.
					14	Broccoli, Brussels sprouts. Use high rate on cabbage loopers. 48-hr re-entry.

[1] PHI = Pre-Harvest Interval.

[2] The carbamates and the pyrethroids have been inconsistent in some areas.

[3] Do not use on muck soils.

SWEDE MIDGE

Identification: Swede midge damage can occur on all brassica crops. Clusters of eggs are laid on the youngest plant tissue. The translucent-to-creamy-yellow-white larvae are 3 mm in length when mature. When disturbed, larvae jump off plants.

Damaged seedlings often appear twisted and may have a noticeable brown scar or a gall at the growing point. If damage occurs before the plant reaches the button stage, the plant will be barren. Later feeding injury results in twisted and distorted heads. Also look for brown, corky scarring along the leaf petiole.

Period of Activity: First-generation swede midge adults emerge from overwintering pupae from mid-May to the beginning of June. It appears that there are four to five overlapping populations of swede midge in Ontario.

Thresholds: None established.

Management Notes: The swede midge is very difficult to manage. Greenhouse transplant growers in quarantined areas must follow the Canadian Food Inspection Agency (CFIA) Swede Midge Certification Protocol (SMCP) to ensure swede midge–free plants to their buyers.

Chop and bury infested residue. Most pupae are found within the top 5 cm of the soil. Deep plowing will reduce the number of viable pupae. Pupae may remain dormant for 2 years, making a 2–3-year rotation away from crucifer crops essential.

Foliar insecticides targeting adult swede midge are used with some success. Systemic insecticides are required to kill the larvae. See Table 9–18, *Brassica Crop Aphid, Swede Midge and Pea Leafminer Control Recommendations*, on page 88.

For more brassica crop insect information, consult the following OMAFRA Factsheets:

- *Caterpillar Pests of Cruciferous Crops,* Order No. 99-035
- *Tarnished Plant Bug Damage on Vegetable Crops in Ontario,* Order No. 98-025
- *Thrips on Onions and Cabbage,* Order No. 99-027
- *The Swede Midge — A New Pest in Crucifer Crops in Ontario,* Order No. 03-035

Nematode Control

See the section *Nematodes*, on page 63, for nematode control recommendations.

Physiological Disorders

CABBAGE SPLITTING

Well-developed cabbage heads may split or burst if rain or a heavy irrigation follows a dry spell. Splitting results from rapid new growth due to increased moisture. Maintain steady plant growth with timely irrigation. Deep cultivation may also break up roots, preventing excessive growth.

BOLTING

Low temperatures early in the growing season may cause premature seedstalk development (bolting). The earlier the seed is sown, the greater the probability of bolting. Bolting may also be caused by extreme changes in temperature, poor soil conditions or low nutrient levels. Some cultivars are more susceptible to bolting.

TIPBURN OF CAULIFLOWER, CABBAGE AND BRUSSELS SPROUTS

Tipburn can occasionally cause severe economic losses in cabbage, cauliflower and Brussels sprouts. Tipburn is a breakdown of plant tissue near the centre of the head in cabbage and Brussels sprouts, and on the inner wrapper leaves of cauliflower. It is a physiological disorder associated with an inadequate supply of calcium in the affected leaf margins, causing a collapse of the tissue and death of the cells.

High temperatures and fluctuating soil moisture conditions hinder the movement of calcium into the leaves, leading to tipburn. Foliar applications of calcium will not necessarily prevent the occurrence of tipburn. Maintain steady plant growth with timely irrigation.

Secondary rot organisms such as *Erwinia* spp. can follow tipburn. Many varieties of cabbage and cauliflower have been noted to be resistant to tipburn problems. See the section *Calcium*, on page 15, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

CAULIFLOWER BUTTONING

Buttoning is the premature formation of a cauliflower curd. Buttoning usually occurs shortly after planting in the field. The curd forms very early in the plant's life, and the leaves are not large enough to nourish the curd to a marketable size.

Losses are usually most severe in early plantings during cold, wet seasons. Conditions that reduce the vigour of the plant and retard vegetative growth appear to encourage buttoning. Some cultivars are more susceptible to buttoning. Conditions that may cause buttoning include:

- too-rapid hardening-off treatment of young plants raised under protection
- insufficient hardening-off treatment of young plants before being planted in the field
- unbalanced soil fertility in the field (particularly low nitrogen)
- low soil moisture
- cold weather, 4°C–10°C (39°F–50°F) for 10 days or more, especially in combination with excess moisture
- certain diseases, insects and trace-element deficiencies, such as clubroot, root maggot and molybdenum deficiency (whiptail)

Harvest

Broccoli

Cut heads when the clusters are green and compact. Open, yellow clusters are undesirable. Terminal broccoli heads are cut with 15–20 cm (6–8 in.) of stem. Lateral shoots from the axils of the leaves develop into marketable heads soon after the terminal head is removed. These laterals produce a continuous crop for several weeks. Some of the new hybrids produce very few laterals. Continuity of production with these cultivars may be obtained by successive plantings in the spring and summer.

Brussels Sprouts

Harvesting should begin when the sprouts are firm and well formed. When hand-picking, break off the leaf below the sprout and remove the sprout. The upper sprouts continue to form and enlarge as the lower ones are harvested. Pick early sprouts as soon as they mature. Otherwise, they will open up, become soft, turn yellow and rot.

For once-over harvest, topping the plants will prevent any further extension of growth and encourage the maturity of the small sprouts at the top of the stem. Topping is normally done when the sprouts at the bottom of the stem are about 12–20 mm ($^1/_2$–$^3/_4$ in.) in diameter. A full stem of uniform, marketable-sized sprouts will develop about 4 weeks later. Do not de-leaf plants more than 1 day before harvest.

Cabbage

Harvest cabbage before the top cover-leaves begin to lose their colour. For best storage results, pick cabbage at a slightly immature stage. Immature heads will retain their colour for a longer period of time.

Cauliflower

A perfect head of cauliflower is essentially pure white or pale cream. Heads exposed to sunlight develop an objectionable yellow pigment. To exclude sunlight, tie the outer leaves over the heads when the heads are 8–10 cm (3–4 in.) in diameter.

In hot weather, blanching may take only 3–4 days. In cool weather, when growth is slow, 8–12 days or more may be required. Mark heads tied at different times with different colours of twine or rubber bands to indicate probable maturity date. The inner wrapper leaves of some cultivars provide natural curd protection without tying.

Storage

Prevent the development of rots and disease in storage by removing field heat from the crop as soon as possible. All brassica crops should be stored at 0°C (32°F) and 95%–100% relative humidity. See Table 6–3, *Storage Life for Fresh Vegetables in Commercial Storage*, on page 48.

CARROTS

Production Requirements

Carrots are a cool-season vegetable. They grow best in deep, well-drained muck and sandy loam soils. The desired pH is 5.5 in muck soils and 6.5 in sandy loam soils. Carrots are extremely sensitive to environmental conditions such as heat, soil compaction, drought stress and saturation. Continuous high temperatures in the latter stages of plant development may reduce yield, retard growth and produce a strong-flavoured, coarse root. Temperatures below 16°C (61°F) also slow plant growth.

Carrots are planted mid-April to late-June. Most carrot varieties mature in 120–180 days. Fresh-market carrots are harvested late-July through October. Processing carrots are harvested October through November.

Average Yields

Crop	per acre	per hectare
Processing	35–40 tons	78–90 tonnes
Fresh market	15–20 tons	34–45 tonnes

Cultivars

Growers and processors are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding and Spacing

The minimum soil temperature for seed germination is 4°C (40°F). Sow as early as soil and weather conditions permit in the spring, up to July 1. Late carrots may "burn off" if they emerge during hot, dry weather. Seed into moisture, 1.2–2 cm (0.5–0.8 in.) deep.

Carrot quality may be improved by using raised beds, 15–20 cm (6–8 in.) high. Beds that are 85 cm (34 in.) wide at the bottom and 50 cm (20 in.) wide on top have yielded good results. Seed carrots in 3 or 4 rows on the centre of the bed at a rate to achieve 26 carrots/m (8 carrots/ft) for processing carrots and 120–140 carrots/m (36–43 carrots/ft.) for fresh-market carrots.

Seeding Rates

	Metric	Imperial
Fresh market:	2–4.5 kg/ha	0.8–1.8 lb/acre
Processing:	1–2 kg/ha	0.4–0.8 lb/acre

Table 9–21.
Carrot Nitrogen Recommendations

Soil	Actual N	
	kg/ha	lb/acre
Mineral Soils		
Preplant	70	62
Side-dress	40	36
Total	**110**	**98**
Muck Soils		
Ontario research has shown that carrots grown on established muck soils receive adequate nitrogen from the soil, and there is no yield response to added nitrogen.		

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10, and Table 9–21, *Carrot Nitrogen Recommendations*, above.

Broadcast and incorporate the recommended preplant nitrogen with all the required phosphate and potash. On mineral soils, apply side-dress nitrogen when the plants are 10 cm (4 in.) tall.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, carrots grown on both mineral and muck soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, carrots grown on both mineral and muck soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Table 9–22.
Carrot Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts per Million (ppm)				
Most recently mature leaf	60 days after seeding	1.8–2.5	0.2–0.4	2–4	2–3.5	0.2–0.5	–	30–60	30–60	20–60	20–40	4–10
	Harvest	1.5–2.5	0.18–0.4	1.4–4	1–1.5	0.4–0.5	–	20–30	30–60	20–60	20–40	4–10

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*. 5th Edition. John Wiley & Sons, Inc. New York.

Magnesium

Magnesium deficiency may occur on carrots. The usual symptoms are yellowing of older leaves while the veins remain dark green. See the section *Magnesium* and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

BORON

Boron deficiency in carrots can cause the growing point to die off or cause internal breakdown of the roots. Boron is often recommended on newly cultivated muck soils. Use caution when applying boron. This nutrient can build to toxic levels quite quickly, harming rotational crops.

Various sources of boron are available. See the section *Boron*, on page 18, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

COPPER

Copper (Cu) deficiency may occur on acid peat and muck soils resulting in carrot roots with poor orange colour. Apply 14–29 kg Cu/ha (12.5–26 lb/acre) on newly cultivated muck soils. Subsequent applications may be made every 2 or 3 years at about one-third the rate recommended for new muck. See the section *Copper*, on page 18, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical.

See Table 9–22, *Carrot Nutrient Sufficiency Ranges*, above. Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing, or a sound soil fertility program.

For more information, see the section *Plant Analysis*, on page 3.

Integrated Pest Management

OMAFRA Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*, provides a comprehensive guide to IPM for carrots.

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information on these common vegetable diseases, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. Also see Table 9–23, *Carrot Seed Treatments*, below.

Table 9–23.
Carrot Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20–40 mL per 100 kg seed	damping-off	For use in commercial seed-treatment plants only. Export use only.
Rovral	iprodione	521 mL per 100 kg seed	seed-borne *Alternaria*	For imported seed only.

LEAF BLIGHTS

Identification: Two different fungi (*Alternaria dauci* and *Cercospora carotae*) and one type of bacteria (*Xanthomonas campestris*) cause leaf blights in carrots. *Alternaria* produces irregular brown spots (often surrounded by yellowish halos), mainly along the edges of carrot leaves. *Cercospora* causes circular grey or brown lesions on both leaves and petioles. Dark-brown lesions with an irregular yellow halo characterize *Xanthomonas.*

Development: Both *Alternaria* and *Cercospora* fungi overwinter in the crop residue of infected carrots. Their spores are dispersed by wind. All three diseases are favoured by warm, humid conditions in the 20°C–30°C (68°F–86°F) range. Symptoms usually appear 10 days after infection.

Thresholds: Apply protectant fungicides when blight is first detected (on 1%–2% of the leaf area.)

Management Notes: After the initial fungicide application, a recommended fungicide should be applied at 7–10-day intervals. Extend the intervals between sprays when the weather is unfavourable for blight. After the leaves have closed over the rows, spray at 7–10-day intervals.

See Table 9–24, *Carrot Disease Control Recommendations*, on page 97.

PYTHIUM
(ROOT DIEBACK, RUSTY ROOT, CAVITY SPOT)

Identification: A variety of symptoms may result from *Pythium* infections, including leaf wilting and discolouration, deformed roots (short, stuffy, forked), rusty red roots and the formation of fibrous roots. Dark, oval lesions on the surface of the carrot root characterize cavity spot.

Development: *Pythium* is a persistent, soil-borne fungus that likes wet soils. Cavity spot lesions usually start to appear in August and September and may slowly enlarge while carrots are in storage.

Thresholds: None established.

Management Notes: Grow resistant cultivars, avoid problem fields and grow carrots on raised beds. See Table 9–24, *Carrot Disease Control Recommendations*, on page 97.

CROWN ROT, VIOLET ROOT ROT

Identification: Foliar symptoms of crown rot and violet root rot tend to appear in patches across the field. Plants become stunted and yellow, followed by wilting and death of the foliage. Root symptoms do not show up until the carrot is mature. Crown rot produces large, grey-brown lesions near the top of the carrot root. Violet root rot covers the root with a thick, purplish fungal layer. When the carrots are pulled, a considerable amount of soil adheres to them.

Development: Appears during mid-summer.

Management Notes: The only practical control is to avoid previously infected areas, rotate for several years with grains and practice strict sanitation procedures to avoid spreading infected soil between fields.

SCLEROTINIA WHITE ROT

Identification: Sclerotinia white rot is typically a disease of stored carrots. The disease comes from the field and may infect plants before harvest. Infection in the field starts at the base of the leaf stalk, causing the petiole to turn brown and die. In storage, infected roots develop a growth of white, cottony fungi and small black sclerotia. The fungus can quickly spread through healthy carrots while in storage.

Development: Optimum temperatures for infection are 15°C–20°C (59°F–68°F). However, sclerotinia white rot can still spread in storage as long as the temperatures are above 0°C (32°F). Development of the disease in the field occurs under cool, wet conditions. Sclerotinia overwinters in crop residue as hard, black sclerotia, which can survive in the soil for many years.

Management Notes: Rotate with onions, beets, spinach or grain crops for 2–3 years. Use wider row spacings to encourage good air movement. Initial infection of storage carrots is less likely to occur if the relative humidity is less than 92% and the field heat is removed as quickly as possible.

ASTER YELLOWS

The symptoms of aster yellows on carrots first appear as a reddening of several leaves. Crown growth becomes yellow and brittle, followed by hairy root development. Aster yellows is transmitted by the aster leafhopper. See the section *Aster Leafhopper*, on page 97.

For more information, see the following OMAFRA Factsheets:

- *Identification and Management of Carrot Root Diseases*, Order No. 98-001
- *Management of Carrot Leaf Diseases*, Order No. 00-045

Table 9–24.
Carrot Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
LEAF BLIGHT						
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.4–3.2 L	1.0–1.3 L	1	
dithiocarbamate (group M3)	mancozeb	Manzate ProStick	2.25 kg	0.9 kg	7	Do not feed treated tops to livestock.
		Dithane DG	2.25 kg	0.9 kg	7	
		Penncozeb 80 WP	2.25 kg	0.9 kg	7	
	zineb	Zineb 80 W	1.1–3.3 kg	0.44–1.32 kg	7	
	metiram	Polyram DF	2.25 kg	0.9 kg	7	Do not feed treated tops to livestock.
carboxamide + QoI (group 7 + 11)	boscalid + pyraclostrobin	Pristine WG	580–735 g	232–294 kg	0	Maximum 6 applications/yr. Do not make sequential applications. Use high rate under heavy disease pressure. 3-day re-entry interval for thinning or hand harvest.
QoI (group 11)	pyraclostrobin	Cabrio EG	0.56–1.1 kg	0.22–0.44 kg	3	**Alternaria leaf blight** Maximum 2 sequential applications. Maximum 3 applications. 72-hour re-entry (hand-thinning).
			560–840 g	0.22–0.33 kg	3	**Cercospora leaf blight** Maximum 2 sequential applications. Maximum 3 applications. 72-hour re-entry (hand-thinning).
carboxamide (group 7)	boscalid	Lance WDG	315 g	126 g	0	**Alternaria leaf blight** Maximum 2 sequential applications. Maximum 5 applications/yr. 4-hr re-entry.
phenylpyrroles + anilino-pyramidines (group 12 + 9)	cyprodonil + fludioxonil	Switch 62.5 WG	775–975 g in a minimum of 200 L water	310–390 g in a minimum of 20 gal water	7	**Alternaria leaf blight.** Maximum 3 applications/yr. Maximum 2 sequential applications. Use high rate under high disease pressure.
CAVITY SPOT						
phenylamides (group 4)	metalaxyl	Ridomil Gold 1G	25 kg	10 kg		215 g/100 m of raised bed. Apply product evenly with seed in the furrow.
CROWN ROT/VIOLET ROOT ROT						
QoI (group 11)	azoxyxstrobin	Quadris Flowable	4–6 ml/100-m row in 50–100 L water	4–6 ml/328-ft row in 4.5–9 gal water	40	Apply in-furrow at seeding or in one banded application over the row after emergence.

[1] PHI = Pre-Harvest Interval.

Insects

CUTWORMS, WIREWORMS

For identification and management information on these common vegetable insects affecting carrots, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–25, *Carrot Insect Control Recommendations*, on page 98.

ASTER LEAFHOPPER

Identification: These small, greenish-grey insects with 6 spots arranged in pairs on top of its head, feed on a wide range of plants, especially grasses, grains and vegetables.

Period of Activity: As the winter grains mature in late May and early June, local first-generation leafhoppers disperse to vegetable crops. Migration of leafhoppers from the U.S. into Ontario may also take place. Migrations into Ontario are not consistent from year to year, because leafhopper movements are regulated by wind and weather patterns. Both local dispersal and long-distance migration influence the incidence and severity of the aster leafhopper.

Table 9–25.
Carrot Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
ASTER LEAFHOPPER						
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1.0 L	1	Use low rate on young plants.
CARROT WEEVIL						
organophosphate (group 1B)	phosmet	Imidan 50 WP	2.25 kg	0.9 kg	40	Maximum 2 applications/yr.
CARROT RUST FLY						
pyrethroid (group 4)	cypermethrin	Ripcord 400 EC	175 mL in 550 L water	70 mL in 55 gal water	35	Maximum 3 applications/yr.
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.44 kg	10	
CUTWORMS[2]						
pyrethroid (group 4)	permethrin	Pounce 384 EC	180–390 mL	72–156 mL		Use high rate on muck soils, large larvae or dry soils. Do not disturb soil for 5 days after application.
	cypermethrin	Ripcord 400 EC	175 mL	70 mL	21	Do not disturb soil for 5 days after application.
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	2.4–4.8 L	0.96–1.9 L	60	24-hr re-entry. Use high rate on large larvae or dry soils.
		Pyrinex 480 EC	2.4–4.8 L in 200–400 L water	0.96–1.9 L in 18–26 gal water	60	24-hr re-entry. 2 applications/yr. Use high rate on large larvae or dry soils.

[1] PHI = Pre-Harvest Interval.

[2] Seedling treatments.

Thresholds: An Aster Yellows Index (AYI) determines the need to treat a crop. To use the AYI, monitor aster leafhoppers with a sweep net. Multiply the number of aster leafhoppers captured in 100 sweeps by the percentage of leafhoppers carrying aster yellows in your area (4%–5% is the currently recommended percent infectivity in Ontario). Use this formula:

Infectivity rate (4%–5%) x # of leafhoppers (per 100 sweeps) = AYI

AYI thresholds in carrots vary depending on varietal tolerance.

Carrot Tolerance[1]	Aster Yellows Index
Resistant	100
Intermediate	70
Susceptible	50

[1] If a carrot variety has not been evaluated for aster yellows tolerance, use an AYI threshold of 70.

Management Notes: Grow resistant cultivars and remove perennial weeds from fields that may act as reservoirs. See Table 9–25, *Carrot Insect Control Recommendations*, above.

CARROT RUST FLY

Identification: The adult rust fly is shiny and black, measuring approximately 6 mm ($^1/_4$ in.) in length. It has an orange head, brown eyes and pale, yellow legs. The larva is cream-white and legless with dark mouthhooks. Larvae feed on the root hairs for up to a month before tunnelling into the carrot, where they continue feeding. Feeding damage from rust fly larvae is usually limited to the lower two-thirds of the root.

Period of Activity: The carrot rust fly overwinters as a pupa in the soil and usually has two generations per year. The first generation often coincides with lilac bloom, the second begins in mid-August. Occasionally, sufficient heat units are accumulated so that a third generation emerges in late September or October. This third generation occurs too late in the season to have any serious effect on the crop.

Thresholds: Control adults if populations reach a level of 0.1 flies/trap/day (fresh market) or 0.2 flies/trap/day (processing). Rust flies are no longer a concern once the crop is within 21 days of harvest. A Growing Degree Day (GDD) model has been developed for carrot rust flies. Using a base of 3°C, first generation adults are expected between 329 and 395 GDD. Second generation adults are expected between 1399 and 1711 GDD. For more information, see the section *Growing Degree Days*, on page 32.

Management Notes: Crop rotation will reduce background populations of the carrot rust fly. Consider late seeding to avoid first-generation damage. Avoid growing carrots in sheltered areas where rust flies are more prevalent.

See Table 9–25, *Carrot Insect Control Recommendations*, on page 98.

CARROT WEEVIL

Identification: The carrot weevil adult is a dark-brown snout beetle (6 mm ($^1/_4$ in.) long). It overwinters in the plant debris of previously infested fields. Feeding damage commonly occurs in the upper third of the root. Developing larvae tunnel into young, slender roots, causing the plants to wilt and die.

Period of Activity: Adult females are not attracted to carrots prior to the first true leaf stage. Egg-laying occurs from mid-May to early June. Eggs hatch in 1–2 weeks, and larvae feed on the roots for at least 3 weeks after emergence. Adults will emerge 2 weeks later. A second generation may occur on early carrot crops under warm weather conditions.

Thresholds: A Growing Degree Day (GDD) model for egg-laying has been developed. Using a base of 7°C, first egg-laying is expected at 147 GDD, which occurs from mid-May to early June. Expect 90% egg-laying at 455 GDD. For more information on GDD models, see the section *Growing Degree Days*, on page 32.

Management Notes: Time treatments to target adults prior to egg-laying. Crop rotation and weed control around field edges may reduce overwintering populations. The egg parasite *Anaphes sordidatus* (a small braconid wasp) provides some biological control. See Table 9–25, *Carrot Insect Control Recommendations*, on page 98.

For more information, consult the following OMAFRA Factsheets and publication:

- *Carrot Insects*, Order No. 93-077
- *The Aster Leafhopper and Aster Yellows*, Order No. 98-057
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*

Nematode Control

For nematode control recommendations, see the section *Nematodes*, on page 63.

Storage

Mature topped carrots can be stored for up to 4–5 months at 0°C (32°F) and a relative humidity of 90%–98%. Rapid cooling of carrots after harvest is very important for reducing storage rots.

Proper sanitation of the storage and handling equipment will also help reduce storage losses. See the section *Storage Sanitation*, on page 50.

See the OMAFRA Factsheet, *Long-Term Storage of Carrots*, Order No. 98-073.

CELERY

Production Requirements

Celery is a cool-season vegetable. Muck soils with high water-holding capacity and a pH of 5.5 are ideal for production. Irrigated celery may also be grown successfully on well-drained mineral soils with an ideal pH of 6.0. Celery can withstand light frosts, but the crop may be damaged if temperatures remain below 0°C (32°F) for a prolonged period of time. Premature seed stalk development or "bolting" may occur if young plants are exposed to temperatures below 13°C (55°F) for 10 days or more.

Most celery varieties mature in 80–90 days after transplanting. Celery harvest begins in late July and continues until several frosts have occurred.

Average Yields

Crop	per acre	per hectare
Processing	20–30 tons	45–68 tonnes
Fresh market	750–1,000 60-lb cartons	2,200 60-lb cartons

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Spacing and Seeding

Early celery is started from seed in the greenhouse at the beginning of February. The minimum soil temperature required for seed germination is 4°C (40°F). If row covers are used, transplanting can occur as early as April 1. Seeding continues through June 1 for July transplanting. Plants for the late crop may be started in irrigated, outdoor seedbeds.

Direct-seed outdoor transplant beds in rows 15–20 cm (6–8 in.) apart, at a rate of 80–110 seeds/m of row (24–34 seeds/ft). The stand will not need thinning before transplanting to the field. Seed may also be broadcast onto a finely prepared bed at a rate of 15 g per 10 m^2. However, the first method provides sturdier plants.

FIELD SPACING

	Metric	Imperial
Row width:	50–55 cm	20–22 in.
In-row spacing:	15 cm	6 in.
Rate:	approx. 140 g seed/ha	approx 56 g seed/acre

Table 9–26.
Celery Nitrogen Recommendations

Soil Type	Actual N	
	kg/ha	**lb/acre**
Mineral Soils[1]		
Preplant	135	120
Side-dress	30[2]	27[2]
Total	**195**	**174**
Muck Soils[1]		
Preplant	80	71
Side-dress	40[2]	35[2]
Total	**160**	**142**

[1] Broadcast and incorporate recommended preplant nitrogen with all the required phosphate and potash.

[2] Up to 2 applications.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application (see Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10).

Broadcast and incorporate recommended preplant nitrogen with all the required potash and potassium. See Table 9–26, *Celery Nitrogen Recommendations*, above.

Phosphorus

Soil tests are required to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, celery grown on both mineral and muck soils is unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L (ppm), seeTable 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, and Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Broadcast and incorporate phosphate and potash requirements prior to planting.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, celery grown on both mineral and muck soils is unlikely to

Table 9–27.
Celery Nutrient Sufficiency Ranges

		N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
Plant Part	**Time of Sampling**	**Percent (%)**						**Parts per Million (ppm)**				
Outer petiole	6 weeks after transplanting	1.5–1.7	0.3–0.6	6–8	1.3–2.0	0.3–0.6	–	20–30	5–10	20–40	15–25	4–6
	at maturity	1.5–1.7	0.3–0.6	5–7	1.3–2.0	0.3–0.6	–	20–30	5–10	20–40	20–40	1–3

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*, 5th Edition. John Wiley & Sons, Inc. New York.

respond to additional potash applications. For soils testing lower than 181 mg K per L (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Calcium

Calcium deficiency results in a physiological disorder known as "black heart." The celery heart turns black, while the outer leaves are unaffected. If celery is under heat and moisture stress, weekly foliar calcium sprays directed into the heart of the plant may reduce black heart symptoms. See the section *Calcium*, on page 15, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Magnesium

Magnesium deficiency appears as yellowing of the tips of older leaves, progressing around leaf margins and between veins. Some celery cultivars are inefficient at taking up magnesium from the soil. Where soil magnesium levels are low, apply foliar sprays starting when the plants are about one-third grown. See the section *Magnesium* and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

BORON

Boron deficiency results in a physiological disease known as "cracked stem" or "cat scratches." Use caution when applying boron. This nutrient can built to toxic levels quite quickly, harming rotational crops.

See Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis can be useful for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the range. Attempting to bring the nutrient analysis up to the higher end of the sufficiency range could possibly result in over-fertilization and may not be economical.

See Table 9–27, *Celery Nutrient Sufficiency Ranges*, above. Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program.

For more information, see the section *Plant Analysis*, on page 3.

Integrated Pest Management

OMAFRA Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario,* provides a comprehensive guide to IPM for celery.

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information on these common vegetable diseases, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59.

Fungicides registered for greenhouse transplant production are listed in Table 9–28, *Celery Transplant Greenhouse Disease Control Recommendations*, on page 102. For more information on vegetable transplant production, see Chapter 5, *Seeding and Transplanting*, on page 37.

Seed Treatment

Buy hot-water-treated seed or sow 3-year-old seed to avoid seed-borne blight fungi. Use seed treated with thiram (dithiocarbamate group) to help prevent damping-off, seedling blight and seed decay. Use 90 g of Thiram 75 WP for every 25 kg (55 lb) of seed.

Table 9–28.
Celery Transplant Greenhouse Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate
DAMPING-OFF, FUNGUS ROOT ROT			
phthalamide (group M4)	captan	Maestro 80 DF[1]	1.25 kg/1,000 L of water Apply 50–85 L of solution per 100 m^2 (1,076 ft^2)
		Supra Captan 80 WDG[1]	
dithiocarbamate (group M3)	oxine benzoate	No-Damp[2]	10 mL/L of water

[1] 48-hr re-entry interval.

[2] Soil treatment.

EARLY BLIGHT, LATE BLIGHT AND BACTERIAL LEAF SPOT

Identification: The symptoms for all three diseases include small yellow specks or lesions on the leaves. Older lesions frequently turn tan-to-brown coloured. Early and late blight lesions may enlarge to 1 cm or more in diameter. Under heavy bacterial leaf spot pressure, lesions will merge and kill infected leaves.

Development: Early blight occurs during mid-summer when heavy evening dews follow sunny, warm, daytime weather. Late blight starts in the lower foliage and moves upwards. All three of these diseases overwinter in crop residue. Following the initial infection, spores are further dispersed by splashing water and the wind.

Thresholds: None established.

Management Notes: If the field has a history of blights, rotate out of celery for at least 2 years. Use hot-water-treated seed and select resistant varieties. Grow seedlings in a commercial soilless mix or heat-pasteurized soil. Rotate outdoor seedbeds. Do not transplant diseased seedlings into the field.

Begin a protectant fungicide program when the seedlings are about 5 cm high. Apply one or two applications before transplanting (see Table 9–28, *Celery Transplant Greenhouse Disease Control Recommendations*, above). After transplanting, begin fungicide applications when plants are one-third grown or when the first signs of disease are detected. See Table 9–29, *Celery Disease Control Recommendations*, on page 103.

FUSARIUM YELLOWS

Identification: Infected plants are often stunted and may be greenish-yellow in colour. The fungus infects the root and basal plate. It causes a darkening of the vascular tissues, followed by basal rot and plant death.

Development: This fungus persists in soil for many years. Fusarium yellows may be introduced by infected transplants, on soil carried by wind or water erosion, and by workers or equipment.

Management Notes: Sanitation is important in preventing the spread of this disease. Avoid cultivation practices that can spread infested soil from one area to the rest of the field. Do not return infested celery trimmings to fields after harvest. Practice a 2- to 3-year rotation with onions or lettuce to reduce spore populations in infested fields. Avoid the use of carrots in the rotation.

Tolerant varieties will withstand moderate levels of the fungus. High fungal populations, excessive heat and drought stress may diminish this tolerance.

PINK ROT (SCLEROTINIA)

Identification: The *Sclerotinia* fungi cause damping-off of seedlings. Infected celery plants develop a pink or reddish-brown water-soaked area on the petioles or stalks. Hard black sclerotia may also be present. Under severe conditions, secondary infections may occur, causing the plant to collapse.

Development: Pink rot is an occasional problem during wet seasons.

Management Notes: Wider row spacings will facilitate airflow and reduce the chance of infection. Where infection has occurred, rotate to onions or another non-susceptible crop. *Sclerotinia* also causes white mould in carrots. See Table 9–29, *Celery Disease Control Recommendations*, on page 103.

CUCUMBER MOSAIC VIRUS (CUMV)

Identification: Symptoms on celery are a mosaic pattern on the leaf, accompanied by downward curling of the petioles. A greenish-yellow discolouration develops along

Table 9–29. Celery Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
CELERY BLIGHT						
chloronitrile (group M5)	chlorothalonil	Bravo 500	1.6–2.4 L	0.6–0.96 L	7	**Early blight:** On a 3–5-day schedule.
			2.4–4.0 L	0.96–1.6 L	7	**Late blight:** On a 8–10-day schedule.
dithiocarbamate (group M3)	mancozeb	Dithane DG	2.25 kg	0.9 kg	14	Wash and trim.
		Manzate Pro-Stick	2.25–3.25 kg	0.9–1.3 kg	14	
		Penncozeb 80 WP	2.25 kg	0.9 kg	14	
	metiram	Polyram DF	2.25–3.25 kg	0.9–1.3 kg	14	After transplanting only. Use higher rate during periods of rain or heavy due. Wash and trim.
	zineb	Zineb 80 W	1.1–3.3 kg	0.44–1.3 kg	14	Wash and trim.
inorganic (group M1)	copper sulphate	Copper 53 W	3.25–6.5 kg	1.3–2.6 kg	1	Use higher rates as crop increases in size.
	copper oxychloride	Copper Spray	4.0 kg in 1,000 L water	1.6 kg in 90 gal water	1	
PINK ROT (SCLEROTINIA)						
biological	*Bacillus subtilis*	Serenade Max	3–6 kg	1.2–2.4 kg		Make the first application approximately 8 weeks before harvest and repeat in 14-day intervals. Apply in sufficient water to ensure thorough coverage to the base of the plants

[1] PHI = Pre-Harvest Interval.

the veins. There may be some crinkling of leaves. Brown, irregularly shaped, sunken lesions also form on the petioles as the virus develops.

Development: This virus is spread by aphids and usually follows periods of high aphid activity.

Management Notes: Control weeds bordering the crop area. Rogue out infected plants if mosaic symptoms are noticed early in the season. See the sections *Aphids*, on page 60, and *Viruses (General)*, on page 59.

ASTER YELLOWS

Identification: Symptoms on celery first appear as a bright yellowing of leaves. Excessive, brittle, yellow crown growth follows, accompanied by severe twisting and secondary bacterial infections. Roguing out infected plants is an effective way to reduce in-field sources of diseases. Aster yellows are transmitted by the aster leafhopper. See the section *Aster Leafhopper*, on page 97.

For more information, see the following OMAFRA Factsheets and publication:

- *Identification and Management of Celery Leaf Blights*, Order No. 00-093
- *Fusarium Yellows of Celery*, Order No. 89-180
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*

Insects

APHIDS, CUTWORMS, TARNISHED PLANT BUG

For identification and management information on these common vegetable insects affecting celery, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–30, *Aphid Control Recommendations for Celery*, on page 104.

ASTER LEAFHOPPERS

See the Aster Yellows Index (AYI) calculation in the section *Aster Leafhopper*, on page 97.

For celery, treat when the AYI equals 30–35. See Table 9–31, *Celery Insect Control Recommendations*, on page 105.

Table 9–30. Aphid Control Recommendations for Celery

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	22.4–34.4 g	7	Maximum 5 applications/yr. Alternate applications with other insecticide families. 12-hr re-entry.
carbamate (group 1A)	pirimicarb	Pirimor 50 DF	300–500 g	120–200 g	10	Maximum 4 applications/yr. 24-hr re-entry.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.75 kg	0.7 kg	14	Trim the celery of all outer leaves.
		Thiodan 4 EC	2.0 L	0.8 L	14	
		Thionex 50WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	naled	Dibrom	1.1–1.65 L in 100–300 L water	0.44–0.66 L in 9–27 gal water	4	
	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.44 kg	21	**Green peach aphid only.** Maximum 4 applications/yr.

[1] PHI = Pre-Harvest Interval.

LEAFMINERS

Identification: The pea leafminer (PLM) has been found in the Holland Marsh area of Ontario. Adults are small, black-to-grey flies with yellow markings. Eggs are laid in the leaves, leaving small "bronzed" puncture marks. Females pierce the leaves to feed on plant sap. Larvae feed between the upper and lower surface of the leaves, creating relatively straight mines that usually follow the veins. Other leafminers tend to make curved, serpentine mines.

Leafminer feeding reduces the plant's photosynthetic capacity. The mines also affect marketability and provide an entrance for disease organisms.

Period of Activity: Optimal temperatures for leafminer development range from 21°C–32°C (70°F–90°F). Egg-laying is reduced at temperatures below 10°C (50°F). The PLM is typically a late-season pest with populations peaking anytime from the end of August through the middle of September.

Thresholds: None established.

Management Notes: Harvesting susceptible crops before the beginning of September may avoid population peaks when the most severe damage occurs. Insecticide applications should be made as soon as PLM adults first appear. Chemical control options are listed in Table 9–31, *Celery Insect Control Recommendations*, on page 105.

CARROT WEEVIL

Carrot weevil can seriously damage celery roots and crowns, causing stunting and plant collapse. For monitoring information, see the section *Carrot Weevil*, on page 99. Chemical control options are listed in Table 9–31, *Celery Insect Control Recommendations*, on page 105.

CABBAGE LOOPER

This is a rare problem in Ontario celery, however, it can cause sporadic damage. The suggested threshold is 5%. See Table 9–31, *Celery Insect Control Recommendations*, on page 105.

For more information on insect pest management in celery, see the following OMAFRA Factsheets and publication:

- *The Aster Leafhopper and Aster Yellows*, Order No. 98-057
- *Caterpillar Pests of Crucifer Crops*, Order No. 99-035
- *Leafminers Attacking Field Vegetables and Greenhouse Crops*, Order No. 00-039
- *Aphids Infesting Lettuce and Celery in Ontario*, Order No. 00-053
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*

Nematode Control

For nematode control recommendations, see the section *Nematodes*, on page 63.

Storage

Do not store celery that has been badly damaged by frost, insects, disease or handling. A relative humidity of 95%–98% and a temperature of 0°C (32°F) are ideal. Store celery in a room that is free from odours. Stalks

Table 9–31.
Celery Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
ASTER LEAFHOPPER						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	86 mL	34 mL	7	Maximum 3 applications/yr.
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	5	
organophosphate (group 1B)	malathion	Malathion 500 E	2.25 L	0.9 L	7	
CARROT WEEVIL						
organophosphate (group 1B)	phosmet	Imidan 50 WP	2.25 kg	0.9 kg	40	Maximum 2 applications/yr.
TARNISHED PLANT BUG						
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.75 kg	0.7 kg	14	Trim the celery of all outer leaves.
		Thiodan 4 EC	2.0 L	0.8 L	14	
		Thionex 50WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.44 kg	21	Maximum 4 applications/yr.
CABBAGE LOOPER						
biological (group 11)	*Bacillus thuringiensis*	Thuricide HPC	2.0–4.25 L	0.8–1.7 L	0	
naturalyte (group 5)	spinosad	Success 480 SC	182 mL	72.8 mL	1	Maximum 3 applications/yr.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.75 kg	0.7 kg	14	Trim the celery of all outer leaves.
		Thiodan 4 EC	2.0 L	0.8 L	14	
		Thionex 50WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	naled	Dibrom	1.1–1.65 L in 100–300 L water	0.44–0.66 L in 9–27 gal water	4	
CUTWORMS[2]						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.48–0.96 L	70	24-hr re-entry. Use high rate on large larvae or dry soils.
		Pyrinex 480 EC	1.2–2.4 L	0.48–0.96 L	70	
LEAFMINERS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	34.3 g	7	Maximum 5 applications/yr for pea leafminer. Alternative applications with other insecticide families. 12-hr re-entry.
chitin biosynthesis inhibitor (group 17)	cyromazine	Citation 75WP	188 g	75.2 g	7	12-hr re-entry. Apply when leafminer larvae first appear. Maximum 5 applications/yr.
(group 6)	abamectin	Agri-mek 1.9% EC	0.6–1.1 L	240–440 mL	14	Use lower rate low pest population pressure. Maximum 4 applications/yr.

[1] PHI = Pre-Harvest Interval.

[2] Seedling treatments.

readily absorb foreign flavours. Field heat should be removed by hydro-cooling or vacuum-cooling before placing in large storage rooms.

Caution

Some individuals may be sensitive to furocoumarins, the natural chemicals found in celery. These substances increase if celery is diseased. Using rubber gloves when handling celery and leg protection when walking in the field will prevent the development of skin rashes.

CUCURBITS

CUCUMBER, MUSKMELON, WATERMELON, PUMPKIN, SQUASH (ALSO KNOWN AS VINE CROPS)

Production Requirements

Cucurbits are warm-season vegetables. They do not tolerate frost. Temperatures below 10°C (50°F) may impact crop growth and negatively affect fruit quality. The vine crops require well-drained, compaction-free locations with ample fertility. The optimum soil pH is 6.1 to 6.5.

Average Time From Flower Set to Harvest

Cucumber (pickling)	4–5 days
Cucumber (slicing)	15–18 days
Muskmelon	40 days
Pumpkin	60–70 days
Summer squash	3–8 days
Winter squash	60–70 days
Watermelon	40 days

Average Yields

Crop	per acre	per hectare
Cucumbers (processing – machine harvest)	4 tons	9 tonnes
Cucumbers (processing – hand harvest)	8–12 tons	18–27 tonnes
Cucumbers (slicing)	200–400 bu	500–1,000 bu
Fresh-market dills	160–400 bu	400–1,000 bu
Muskmelons	25 bins	60 bins
Pumpkins	50 bins	125 bins
Squash (winter)	15–20 bins	40–50 bins
Watermelon	15–25 ton	34–56 tonnes
Zucchini	700 ½-bushel boxes	1,600 ½-bushel boxes

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Processing cucumber hybrids have a predominately female (gynoecious) flowering habit. However, not all gynoecious hybrids produce 100% female flowers. Ontario day-lengths and temperatures may be responsible for the presence of male flowers on these hybrids. All gynoecious hybrid seed contains 10%–15% standard (monoecious) cultivar, added as a pollinator. For satisfactory fruit set, 10%–20% of the plants should contain a large number of male flowers.

In other vine crops, the normal ratio of male to female flowers is often 10 male:1 female. This ratio can occasionally reach 100:1 without a significant impact on yield.

Seeding and Spacing

Total cucurbit yields tend to increase with plant density. Processing cucumbers for machine harvest benefit the most from close spacings. In other vine crops, high plant populations may result in harvest problems due to excessive vine growth. An overly dense canopy is also more conducive to disease pressure.

In pumpkins and squash, fruit size tends to decrease as plant density increases. Larger-sized pumpkin and winter squash varieties will benefit from wider spacing. However, extremely wide rows are slow to close canopy, resulting in higher levels of weed pressure.

Plant seeds into moisture, no more than 2–2.5 cm (1 in.) deep. Deeply planted seed is often slow to emerge, resulting in lower plant populations. Quick, uniform emergence is essential to avoid uneven stands weakened by insects and disease. Delay planting until the soil temperature is 15°C (59°F) or higher. The optimum soil temperature range at planting is 25°C–30°C (77°F–86°F.)

Pickling cucumbers are usually field-seeded from late May to early June for the hand-pick crop. Seeding for mechanical harvesting can be done until mid-July, depending on the buyer's specifications.

Pumpkins and squash for the Hallowe'en market are usually seeded from late May to mid-June. Plant melon transplants after the risk of spring frost has passed (see Table 4–1, *Average Frost-Free Period in Climatic Zones of Ontario (1961–90)*, on page 31).

See Table 9–32, *Cucurbit Crop Spacing*, on page 107.

> For information on producing vine crop transplants, see the section *Transplanting*, on page 39.

Seedless Watermelon Production

Triploid watermelons will not set fruit unless pollinated by a normal (diploid) watermelon variety. Use one pollinator plant for every 2 seedless ones. For the best results, mix the pollinator varieties in the same row as the triploids. Plant a pollinator with a different fruit type to distinguish it from the seedless variety at time of harvest.

Table 9–32. Cucurbit Crop Spacing

Crop	Metric		Imperial	
	Row Spacing	In-Row Spacing	Row Spacing	In-Row Spacing
Cucumbers				
Fresh	1.2–1.8 m	30 cm	4–6 ft	12 in.
Cucumbers (processing)				
Hand-pick	1.1–1.2 m	10–15 cm	3.5–4 ft	4–6 in.
Machine harvest	50–75 cm	10 cm	20–30 in.	4 in.
Pumpkins & Squash[1]				
Standard types	1.5–3 m	60–150 cm	5–10 ft	2–5 ft
Semi-bush types	1.2–1.5 m	45–90 cm	4–6 ft	1.5–3 ft
Small bush types	0.9–1.2 m	45–90 cm	3–6 ft	1.5–3 ft
Melons[2]				
Muskmelons	1.5–1.8 m	60–90 cm	5–6 ft	2–3 ft
Watermelons	1.8–2.5 m	90–120 cm	6–8 ft	3–4 ft

[1] Varieties with large fruit size (over 30 lb) benefit from wider rows and plant spacings. Gourds and mini-pumpkins respond to significantly higher plant populations (up to 6,000 plants/acre).

[2] Approximately 2.2 kg of seed are required to produce enough melon seedlings for 1 ha.

Under cool or stressful growing conditions, some seed development may occur in seedless watermelons.

Plasticulture

Vine crops (especially musk and watermelons) respond well to plastic mulch, row covers and drip irrigation. However, keep in mind that all vine crops are very sensitive to low temperatures. Row covers may not provide significant frost protection if the crop is planted too early. Monitor the temperature inside the row cover regularly. Ventilate when the temperature inside reaches 35°C (95°F) or higher. Remove the cover once the risk of cold temperatures has passed. Covers must be removed prior to pollination. To control weed growth under the mulch, choose one that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch. For more information, see the section *Season Extension*, on page 34.

Pollination

All the vine crops depend on insects to transfer pollen from the male to the female blossoms. Each female blossom must be visited 15–20 times for adequate pollination to occur. Poorly pollinated fruit exhibit awkward shape and poor size. Hollow heart of watermelons may be linked to poor pollination.

Table 9–33. Cucurbit Nitrogen and Potash Injection Schedules

Stage	Rate per week
Transplanting to fruit set	5 kg/ha (4.5 lb/acre)
Fruit sizing to harvest	10 kg/ha (9 lb/acre)
During harvest	5 kg/ha (4.5 lb/acre)

Native pollinators are commonly found in many pumpkin and winter squash fields. They are less common in cucumbers, muskmelons and watermelons. Assess all vine crop fields for bee activity at early bloom. If there is adequate pollination occurring, a clear "humm" of activity can be heard in the field in the early morning hours. Consider introducing one colony of honeybees for every hectare (2.5 acres). Aim to have the hives in the field at first bloom.

Insecticides will poison bees. Spray only in the evening or at night, after bees have finished foraging for the day. If possible, remove hives from the field prior to spraying. See the section *Prevent Bee Poisoning*, on page 53.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Apply up to 110 kg N/ha (98 lb N/acre). Broadcast 65 kg N/ha (58 lb/acre) and all the phosphate and potash required prior to planting. Side-dress the remainder of the nitrogen before the vines start to run. On sandy soils, a second application may be necessary after the vines begin to run.

Alternatively, up to 100 kg (90 lb) of N + K_2O/ha can be applied in a band, 5 cm to the side and 5 cm below the seed at planting. The remainder of the fertilizer requirements should be broadcast before planting. Over-application of nitrogen may result in excessive vine growth and reduced fruit yields.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, cucurbit fields are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Table 9–34.
Cucurbit Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts per Million (ppm)				
Cucumber												
Most recently mature leaf	before bloom	3.5–6	0.3–0.6	1.6–3	2–4	0.58–0.7	0.3–0.8	40–100	30–100	20–50	20–60	5–20
	early bloom	2.5–5	0.25–0.6	1.6–3	1.3–3.5	0.3–0.6	0.3–0.8					
Muskmelon												
Most recently mature leaf	12-in. vines	4.0–5.0	0.4–0.7	5–7	3–5	0.35–0.45	0.2–0.5	40–100	20–100	20–60	20–80	5–10
	early fruit set	3.5–4.5	0.25–0.4	1.8–4	1.8–5	0.3–0.4	0.2–0.5					
Pumpkin												
Most recently mature leaf	5 weeks after seeding	3–6	0.3–0.5	2.3–4	0.9–1.5	0.35–0.6	0.2–0.4	40–100	40–100	20–50	25–40	5–10
	8 weeks from seeding	3–4	0.25–0.4	2–3	0.9–1.5	0.3–0.5	0.2–0.4					
Squash												
Most recently mature leaf	early fruit	3–5	0.25–0.5	2–3	1–2	0.3–0.5	0.2–0.5	40–100	40–100	20–50	25–40	5–20
Watermelon												
Most recently mature leaf	last cultivation	3–4	0.25–0.5	3–4	1–2	0.25–0.5	0.2–0.4	30–100	20–100	20–40	20–40	5–10
	first flower	2.5–3.5	0.25–0.5	2.7–3.5	1–2	0.25–0.5	0.2–0.4					
	first fruit	2–3	0.25–0.5	2.3–3.5	1–2	0.25–0.5	0.2–0.4					

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*, 5th Edition. John Wiley & Sons, Inc. New York.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, cucurbit fields are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Fertigation

For fertigated vine crops, broadcast all the phosphate requirement and approximately 30%–50% of the nitrogen and potash requirements prior to planting. The remainder should be injected through the drip irrigation system at the rates shown in Table 9–33, *Cucurbit Nitrogen and Potash Injection Schedules*, on page 107.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information see the section, *Plant Analysis*, on page 3.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–34, *Cucurbit Nutrient Sufficiency Ranges*, above.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

Use sterile soil or soil-less mix for growing seedlings. For identification and management information on these common vegetable diseases, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. Also see Table 9–35, *Cucurbit Seed Treatments*, below.

Table 9–35.
Cucurbit Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20–40 mL per 100 kg seed	pythium damping-off	For use on imported seed only. No domestic treatment.
Thiram 75 WP	thiram	50 g per 25 kg seed	seed decay and damping-off	

Table 9–36.
Cucurbit
Downy Mildew Fungicide Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
BROADSPECTRUM PREVENTATIVE FUNGICIDES						
Begin applications no later than vine development.						
chloronitrile (group M5)	chlorothalonil	Bravo 500	4.8 L	1.9 L	1	
dithiocarbamate (group M3)	mancozeb	Dithane DG	1.1–3.25 kg	0.44–1.3 kg	14	
		Manzate Pro-Stick	2.25–3.25 kg	0.9–1.3 kg	14	
		Penncozeb 80 WP	1.1–3.25 kg	0.44–1.3 kg	14	
DOWNY MILDEW–TARGETED PREVENTATIVE FUNGICIDES[2]						
Begin applications when weather conditions favour downy mildew or if downy mildew is identified in the Great Lakes region.						
QiL (group 21)	cyazofamid	Ranman 400SC	150–200 mL in 200–600 L water	40–80 mL in 20–60 gal water	1	Maximum 6 applications/yr. Do not make sequential applications. 12-hour re-entry. 30-day plant back interval.

[1] PHI = Pre-Harvest Interval.

[2] Contact the OMAFRA Vegetable Crops Specialist or the Ontario Processing Vegetable Growers for a list of additional downy mildew–targeted fungicides registered under Emergency Use or the Minor Use Program.

DOWNY MILDEW

> Downy mildew is a serious disease of cucurbit crops. Cucumbers are the most susceptible to infection, however melons and other vine crops can be affected by certain pathotypes of this disease. Downy mildew is wind borne and highly infectious. It can destroy an unprotected crop in less than 1 week.

Identification: Downy mildew–infected leaves develop pale green areas on the upper leaf surface. The corresponding lower leaf surface may be covered with a downy, grey-to-purple mould with visible black spores (sporangia). As the infection progresses, the lesions become yellow, then brown and necrotic.

In cucumbers, the lesions are often confined by the leaf veins and take on an angular appearance. During favourable environmental conditions, downy mildew can completely kill a crop within a week of the initial infection. Fruit from infected plants are usually undersized, deformed and unmarketable.

Development: Downy mildew is favoured by cool, wet or humid weather conditions. Spore production is highest at temperatures of 15°C–20°C (59°F–69°F). Under favourable weather conditions, the pathogen will produce new innoculum in as little as 4 days.

Thresholds: Downy mildew must be managed preventatively. There are no thresholds.

Management Notes: Follow a basic 7–14-day preventative program using one of the broad spectrum fungicides listed in Table 9–36, *Cucurbit Downy Mildew Fungicide Recommendations*, above. Initiate the program no later than runnering. If suitable environmental conditions exist during the early stages of crop development, use a banded application to protect the young plants.

Switch to one of the targeted downy mildew fungicides listed in Table 9–36, *Cucurbit Downy Mildew Fungicide Recommendations*, above, if downy mildew is identified in the Great Lakes region, **OR** during prolonged periods of cool, humid weather **OR** when there are cool nighttime temperatures followed by heavy dewfall. If downy mildew has been identified in an area, maintain a strict 5–7-day fungicide schedule.

Apply all downy mildew fungicides preventatively. Always rotate between different fungicide groups.

Ensure good spray coverage. Select nozzles and set the air pressure to deliver a medium-to-fine droplet size. All fungicides should be applied in a minimum 30 gal water/acre (or higher).

Growers who plant cucurbit transplants should ensure that the transplants are free from disease and grown in a greenhouse dedicated solely for transplant production. For cucumbers grown under plastic tunnels, apply a preventative fungicide immediately after transplanting and a second application as soon as the row covers are removed.

Note: the downy mildew–targeted fungicides will not provide protection against powdery mildew, scab and other vine crop diseases.

POWDERY MILDEW

Identification: Initial symptoms develop on the undersides of older, shaded leaves. The white, powdery growth will spread to the upper leaf surface and down the petiole. Infected leaves and stems wither and die prematurely, impacting both yield and fruit quality.

Development: This disease does not overwinter in Ontario. Spores usually arrive (from the southern U.S. and Mexico) in mid-summer. Peak infection periods occur when temperatures are in the range of 20°C–26°C (68°F–80°F). Disease development slows when temperatures climb above 26°C (80°F).

Infections develop at relatively low humidity (<20%) levels, although humid weather conditions and heavy dews lead to more rapid disease development.

Thresholds: Begin applying protectant fungicides at the first sign of disease. Late July through August is usually the most criticial powdery mildew control period.

Management Notes: There is a wide selection of powdery mildew–resistant varieties available for all types of vine crops. Good spray coverage on both the upper and lower leaf surfaces is important. Use high water volumes. See Table 9–37, *Cucurbit Disease Control Recommendations*, on page 111.

BACTERIAL WILT

Identification: Infected leaves develop dull green patches. As the vascular system becomes blocked with bacterium, the runners (and eventually the whole plant) become wilted. Plants ultimately turn yellow and die.

Development: This disease overwinters in the stomachs of adult cucumber beetles. Beetles inject the bacterium into the plant as they feed. Vine crops species and cultivars differ in their susceptibility to bacterial wilt. Generally speaking, cucumbers and melons are very susceptible.

Management Notes: Control cucumber beetle feeding to prevent the spread of this disease. See the section *Cucumber Beetles*, on page 113.

ANGULAR LEAF SPOT

Identification: Small, "water-soaked" lesions develop on infected leaves. These lesions will expand in size until they are confined by the veins, resulting in an angular appearance. Affected areas turn brown, and the centres fall out, leaving small holes in the leaf.

Development: This bacterial disease is seed-borne. Bacteria also survive in infected crop residue. In wet conditions, it spreads rapidly across the field through splashing rainwater or machinery.

Thresholds: None established. Apply copper fungicides at the first sign of infection.

Management Notes: Angular leaf spot is more prevalent in pumpkins and squash. There is good varietal resistance available in cucumbers. Purchase pathogen-free seed, do not save seed from infected fields. A two-year rotation away from cucurbit vine crops will reduce overwintering innoculum. See Table 9–37, *Cucurbit Disease Control Recommendations*, on page 111.

SCAB, ANTHRACNOSE AND ALTERNARIA

Identification: All these diseases cause leaf spotting and (occasionally) leaf distortion. Scab leaf lesions are small, numerous and pale yellow-to-white in colour. Scab fruit infection occurs as large, sunken craters with corky margins.

Anthracnose leaf spots are dry and reddish brown, often with a lighter yellow border. Severely infected leaves become dry, cracked and ragged-looking. Anthracnose-infected fruit develop sunken lesions, varying in colour from red-brown to black. Under humid conditions, these lesions may develop masses of salmon pink spores.

Alternaria lesions start as small, yellow-to-brown flecks. As the flecks enlarge in size, concentric rings become apparent. On muskmelons, alternaria lesions may grown as large as 1 cm in diameter. There are somewhat smaller on watermelons. If left untreated, the lesions often grow together, causing the entire leaf to turn brown, wither and die. The resulting reduction in the leaf canopy often causes an increase in sunscald and damage to mature fruit.

These diseases may also develop on fruit in storage.

Development: Scab development favours cool, dry days interspersed with moisture and/or heavy dews. Field infection occurs at temperatures from 17°C–20°C (63°F–68°F). Melons may develop symptoms in storage at temperatures as low as 8°C (46°F).

Table 9–37. Cucurbit Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
ANGULAR LEAF SPOT						
inorganic (group M1)	copper sulphate	Copper 53W	2.5–3.0 kg	1–1.2 kg	1	Also controls anthracnose.
	copper hydroxide	Parasol Flowable	2.3–3.1 L	0.9–1.2 L	1	Cucumbers only.
	copper oxychloride	Copper Spray	4.0 kg	1.6 kg	1	Also controls anthracnose.
POWDERY MILDEW						
chloronitrile (group M3)	chlorothalonil	Bravo 500	4.8 L	1.9 L	1	
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g in 350 L water (30 gal water)	224–336 g in 350 L water (30 gal water)	3	Maximum 4 applications/yr. Do not make more than 1 application before alternating with a different fungicide family. 24-hr re-entry.
inorganic	potassium bicarbonate	MilStop	2.8–5.6 kg	1.1–2.25 kg	0	Suppression only. Ensure thorough spray coverage.
ALTERNARIA, ANTHRACNOSE, GUMMY STEM BLIGHT AND SCAB						
dithiocarbamate (group M3)	mancozeb	Dithane DG	1.1–3.25 kg	0.44–1.3 kg	14	Alternaria, anthracnose, gummy stem blight and scab.
		Manzate Pro-Stick	2.25–3.25 kg	0.9–1.3 kg	14	
		Penncozeb 80WP	1.1–3.25 kg	0.44–1.3 kg	14	
chloronitrile (group M5)	chlorothalonil	Bravo 500	4.8 L	1.9 L	1	**Anthracnose and scab.**
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g in 350 L water	224–336 g in 30 gal water	3	**Alternaria, anthracnose and gummy stem blight.** Maximum 4 applications/yr. Do not make more than 1 application before alternating with a different fungicide family. 24-hr re-entry.
carboxamide (group 7)	boscalid	Lance WDG	460 g	184 g	0	**Alternaria and gummy stem blight.** Maximum 4 applications/yr. 4-hr re-entry.
phthalimide (group M4)	captan	Maestro 80DF	2.25–4.25 kg	0.9–1.7 kg	2	**Anthracnose and scab.** Cucumber only. Use low rate on young plants. Aerial applications permitted. 48-hr re-entry.
		Supra Captan 80 WDG	2.25–4.25 kg	0.9–1.7 kg	2	

[1] PHI = Pre-Harvest Interval.

Anthracnose is a late-season disease. It prefers warm temperatures of 22°C–27°C (72°F–81°F) and high relative humidity (100% for 24 hr).

Alternaria can develop under a wide range of environmental conditions. It can survive in temperatures from 12°C–30°C (54°F–86°F.)

Thresholds: None established. Scab infections may occur in all vine crops. Alternaria and anthracnose are more commonly found in muskmelon and watermelon crops.

Management Notes: Practice a 2–3-year rotation away from all vine crops. Avoid night-time overhead irrigation during cooler weather. See Table 9–37, *Cucurbit Disease Control Recommendations*, above.

GUMMY STEM BLIGHT (also known as BLACK ROT OR ALLIGATOR SKIN)

Identification: Circular tan-to-dark brown lesions develop between healthy green leaf veins. Infected leaves often curl inwards. Stem cankers often produce a gummy brown exudate. Later in the season, gummy stem blight infections cause fruit decay, often accompanied by copious amounts of black spores (known as black rot.) On butternut squash, distinct circular bronze patterns (alligator skin) develop on the surface of infected fruit.

Development: Gummy stem blight survives on crop residue and in infected seed. Infections often occur in "hot spots" spreading out from a single infected seed.

Thresholds: None established. Apply fungicides at the first sign of foliar symptoms.

Management Notes: Follow a 2–3-year crop rotation and use certified, treated seed. Do not save seed from infected fields. See Table 9–37, *Cucurbit Disease Control Recommendations*, on page 111.

FUSARIUM WILT

Identification: Fusarium wilt is a serious problem in muskmelons and an occasional problem in other vine crops. Early-season fusarium wilt infections result in the damping-off of seedlings and transplants. Later infections cause the foliage to turn a dull grey-green and wilt, followed by a general yellowing and defoliation. Fusarium infection causes the vascular tissue to turn reddish-brown. A gummy exudate may form on the underside of infected vines.

Muskmelons from infected fields may develop raspberry-pink fungal growths on the underside of the fruit.

Development: Fusarium wilt may attack the plant at any stage. Outbreaks often follow periods of crop stress, including hot, dry weather conditions. Soil temperatures of 18°C–25°C (64°F–77°F) support rapid disease progression. Vine crops grown in slightly acidic soils (pH 5.0–5.5) may be more prone to fusarium infections. The fungal spores survive in the soil for many years.

Thresholds: None established. Foliar fungicides will not control this disease.

Management Notes: Fusarium-resistant vine crop cultivars are available. As several different races of fusarium exist, look for varieties with multiple resistance genes.

Follow a 3–4-year rotation away from all vine crops and use only sterile, soil-less mix for vine crop transplants. Lime soil to a target pH of 6.0–6.5 and avoid over-fertilization, especially with fertilizers containing ammonium. Maintain adequate soil moisture levels, especially during fruit-set and sizing.

PHYTOPHTHORA BLIGHT

Identification: Phytophthora symptoms include foliar blight, fruit rot and stunting. The foliar blight/crown rot phase often starts at the growing point. Dark-green lesions form on the crown, eventually girdling it and causing the entire plant to turn brown, collapse and die.

Fruit infections begin as a large water-soaked lesion. White spores resembling powdered sugar develop on the surface of the lesion.

Development: Phytophthora spreads rapidly during warm, wet weather. Ideal conditions for infection are moist soils above 18°C (65° F) and air temperatures between 24°C and 29°C (75°F and 85° F). Levels of soil inoculum build up over time, especially under intensive vine crop and/or solanaceous crop rotations.

Thresholds: None established.

Management Notes: Rotate fields for a minimum of 3 yr away from all host crops. **Do not plant cucurbit crops in a field that has a history of phytophthora infections.** Select well-drained fields. Minimize soil compaction and avoid excessive irrigation, especially in overhead systems. Clean farm equipment if travelling between infected and non-infected fields.

SEPTORIA LEAF SPOT

Septoria infections cause circular, white-to-light brown leaf lesions. Fruit lesions are raised and pimple-like. Septoria occurs only sporadically in Ontario. Muskmelons, pumpkins and winter squash are all susceptible. Septoria is more common during unseasonably cool summers or during late fall.

CUCUMBER MOSAIC VIRUS

This virus is transmitted by aphids and cucumber beetles. Transmission occurs very quickly (in less than 1 min). As a result, aphid control will not necessarily prevent an infestation. Use of resistant cultivars is the best available means of preventing yield losses.

Control perennial weeds in adjacent fencerows. Milkweed, ground cherry, pokeweed, chickweed and mother-wort are alternative hosts to the mosaic virus. See the sections *Aphids*, on page 60, and *Viruses (General)*, on page 59.

Insects

SEEDCORN MAGGOTS, WIREWORMS, APHIDS, CUTWORMS

For identification and management information on these common vegetable insects affecting vine crops, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–38, *Cucurbit Insect Control Recommendations*, on page 113.

Table 9–38.
Cucurbit Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
CUCUMBER BEETLES AND APHIDS						
Planting Treatment						
neonicotinoid (group 4)	imidacloprid	Admire 240 F	Soil: 18 mL per 100 m row		21	One application/yr applied in-furrow at planting or banded soon after planting. 24-hr re-entry.
			Transplant water: 25 mL per 1,000 plants		21	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0 kg	0.4 kg	2	Will also control squash vine borer.[2]
		Thionex 50 WP	1.1 kg	0.44 kg	2	
		Thiodan 4 EC	1.5 L	0.6 L	2	
inorganic	kaolin clay	Surround WP	12.5 –25 kg in 500 L water	5–10 kg in 45 gal water	0	Cucumber beetle control only. Maximum 5 applications/yr.
organophosphate (group 1B)	malathion	Malathion 25 W	4.25 kg	1.7 kg	3	Cucumbers, squash, pumpkins.
			4.0–5.5 kg	1.6–2.2 kg	3	Melons.
		Malathion 500 E	1.8 L	0.72 L	3	Cucumbers, squash, pumpkins.
			2.25–2.75 L	0.9–1.1 L	3	Melons.
TWO-SPOTTED SPIDER MITE						
diphenylethane (group 3)	dicofol	Kelthane 50 W	1.0–1.25 kg	0.4–0.5 kg	7	Maximum 1 application/yr. Use high rate on large plants.
CUTWORMS						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.48–0.96 L	60	Cucumbers only. Apply at 2–5-leaf stage. 24-hr re-entry.
		Pyrinex 480 EC	1.2–2.4 L	0.48–0.96 L	60	
carbamate (group 1A)	carbaryl	Sevin XLR	2.5 L	1 L	5	Climbing cutworms only. Do not apply during bloom.

[1] PHI = Pre-Harvest Interval.

[2] Butternut squash is resistant to squash vine borer.

CUCUMBER BEETLES

Identification: Striped cucumber beetles are 6–7 mm (1/4 in.) long with 3 black stripes. The less common, spotted cucumber beetle is slightly larger. While feeding damage can seriously harm seedlings, the main threat to vine crop yield is the transmission of bacterial wilt.

Period of Activity: Beetles usually arrive in cucurbit fields as the crop begins to emerge. They may be present in the field throughout the summer. However, early populations are generally the most damaging. Late-season feeding on the fruit may reduce marketable yields.

Thresholds: Treat when beetles exceed 0.5–1 per plant. Use the lower threshold on bacterial wilt-susceptible varieties. A follow-up spray may be necessary, as beetle emergence is often staggered.

Management Notes: Cucumber beetles tend to congregate in certain areas of the field, making them an excellent candidate for spot spraying. Vine crops vary in their attractiveness to beetles. Zucchini and pumpkins are highly attractive, cucumbers and melons less so. The more attractive species offer opportunities for trap cropping.

Bee Warning

The insecticides listed in Table 9–38, *Cucurbit Insect Control Recommendations*, are toxic to bees. Apply insecticides in the evening when bees are not working in the field. If hives are in the crop, remove them or close them off when treating the field.

See Table 9–38, *Cucurbit Insect Control Recommendations*, above.

TWO-SPOTTED SPIDER MITE

Identification: The adult mite is approximately 0.5–1 mm in length, barely visible to the naked eye. It is a translucent-yellowish colour with two dark spots on the sides of its abdomen. Spider mites feed through sucking mouth parts. Injury first appears as a bronzed, stippled effect. Severe feeding causes curling and drying of the leaves. Symptoms are often confused with drought stress.

Period of Activity: Mite activity is most common in hot, dry conditions. They often move into vine crops (especially watermelons) following wheat harvest.

Thresholds: None established. Melon plants are most susecptible to damage prior to first harvest.

Management Notes: Heavy rain or overhead irrigation often reduces mite populations to tolerable levels. See Table 9–38, *Cucurbit Insect Control Recommendations*, on page 113.

LEAFHOPPERS

High levels of leafhoppers occasionally appear in vine crops after hay is cut in the spring. Feeding damage plugs the leaf veins causing V-shaped or circular yellow lesions on the leaf margins. This pest does not usually affect yields. See the section *Potato Leafhopper*, on page 75, for more information.

SQUASH BUG

Identification: Squash bug eggs are laid in small clusters, usually on the underside of the leaf. The bullet-shaped eggs are yellow when first laid, turning reddish-brown as they mature.

Squash bug nymphs have pear-shaped, pearly grey bodies with darker legs and antennae. Squash bug adults have flattened, tear-shaped bodies. They are brownish-grey with yellow-to-orange markings.

Squash bugs are commonly found in fairly large colonies with several different stages of development present at the same time.

Period of Activity: Adults emerge from overwintering sites in the spring and begin laying eggs in vine crop fields in early June. Squash bugs may be present in vine crop fields throughout the growing season.

Thresholds: One egg mass per plant. Insecticides are most effective when targeted at small young nymphs.

Management Notes: Squash bugs like to hide in well-sheltered locations. Good weed control will help reduce the potential squash bug habitat in the field.

SQUASH VINE BORER

Fleshy, white larvae feed inside the stems and fruit of gourds, pumpkins and squash. This pest is rarely a problem in commercial fields, as borers are generally controlled by cucumber beetle sprays. If feeding occurs, spray the base of plants thoroughly with one of the insecticides recommended in Table 9–38, *Cucurbit Insect Control Recommendations*, on page 113.

Nematode Control

For nematode control recommendations, see the section *Nematodes*, on page 63.

Curing and Storing Pumpkin and Squash

Curing some types of pumpkin and squash can decrease the water content and improve eating quality. Butternut and hubbard cultivars respond to this treatment, but storage life may be shortened. Curing acorn-type squashes decreases the storage life and eating quality. If deemed necessary, fruit may be cured for 10–20 days at 24°C–27°C (75°F–81°F). Windrowing squash and pumpkins in the field prior to storage often acts as a natural curing process.

Vine crops vary significantly in their storage life expectancy. Vine crops are susceptible to cold injury, which appears after the fruit has been brought back to room temperature.

For pumpkins and winter squash, maintain storage temperatures between 10°C–15°C (50°F–59°F). Aim for 50%–70% relative humidity. High humidity levels will increase storage rots, while dry conditions will increase weight loss and shrinkage. Weight loss should be kept below 15%. See Table 9–39, *Pumpkin and Squash Storage Expectancy*, below.

For information on storing cucumbers, melons and summer squash, see Table 6–3, *Storage Life for Fresh Vegetables in Commercial Storage*, on page 48.

Table 9–39.
Pumpkin and Squash Storage Expectancy

Type	Storage Expectancy
Acorn	4–7 weeks
Pumpkins	8–12 weeks
Butternut	8–12 weeks
Buttercup	10 weeks
Turban	12 weeks
Hubbard	6 months

EGGPLANT

Production Requirements

Well-drained sandy loams, with relatively high organic matter levels and a pH of 5.5–6.5, are best for eggplant production. Eggplant require about 55–80 days from transplanting to harvest and 25–40 days from pollination to marketable fruit.

Average Yields

Crop	per acre	per hectare
Eggplant	500 bu graded product	1,250 bu graded product

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding and Spacing

Row spacing:	90–120 cm	36–48 in.
In-row spacing:	45–60 cm	18–24 in.
Rate:	Approx. 200–300 g of seed will produce enough transplants for 1 ha (3–4 oz/acre).	

Plasticulture

Eggplant responds well to plastic mulches and row covers. However, eggplant is very susceptible to low temperatures. Row covers may not provide significant frost protection. Monitor the temperature under the row cover regularly and ventilate when it reaches 35°C (95°F) or higher. Remove the cover once conditions are favourable for good growth and prior to pollination. To control weed growth under the mulch, choose one that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch. For more information, see the section *Season Extension*, on page 34.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Table 9–40.
Transplant Starter Solution Recommendations

Soil Temperature	Starter Concentration[1]
<18°C (64°F)	Use full label rate as recommended.
18°C–27°C (64°F–81°F)	Use half of recommended rate.
>27°C (81°F)	Starter not normally required.

[1] Under high temperature or dry conditions or in sandy soils with less than 2% organic matter, use half the recommended rates.

Apply up to 70 kg N/ha. Broadcast 35 kg N/ha and all the required phosphate and potash before planting. The remainder of the nitrogen should be side-dressed 3–4 weeks after field setting.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, eggplant is unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, eggplant is unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Starter Solution

At transplanting, apply a high-phosphorus starter solution. Starter fertilizer is especially important when planting in cool soils. Starter fertilizers are available in several forms, including liquids (10-34-0 or 6-24-6), soluble or granular materials (10-30-20 or 10-52-10). Apply according to the recommendations in Table 9–40, *Transplant Starter Solution Recommendations*, above.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher

Table 9–41.
Eggplant Nutrient Sufficiency Ranges

		N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
Plant Part	**Time of Sampling**	**Percent (%)**						**Parts per Million (ppm)**				
Most recently mature leaf	early fruit set	4.2–5	0.3–0.6	3.5–5	0.8–1.5	0.25–0.6	0.4–0.6	50–100	50–100	20–40	20–40	5–10

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers,* 5th Edition. John Wiley & Sons, Inc. New York.

end of the range could possibly result in over-fertilization and may not be economical. For more information, see the section *Plant Analysis*, on page 3.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–41, *Eggplant Nutrient Sufficiency Ranges*, above.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

To prevent damping-off, use sterile, soilless mix and treat seed with thiram (dithiocarbamate group) seed protectant. Use 65–80 g of Thiram 75 WP per 25 kg of seed. See the section *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)*, on page 59, for more information.

Fungicides registered for greenhouse transplant production are listed in Table 9–42, *Greenhouse Eggplant Transplant Production Disease Control Recommendations*, below. For more information on vegetable transplant production, see Chapter 5, *Seeding and Transplanting*, on page 37.

VERTICILLIUM WILT

Identification: Extensive yellowing develops on the older leaves, followed by wilting of the plant and leaf drop. The yellowing may move in from the leaf margin in a characteristic "V" shape. When split length-wise along the stem, infected plants exhibit discolouration of the vascular tissue.

Period of Activity: All season. Symptoms are often more severe after fruit set or during dry periods. Plant-parasitic nematodes may further aggravate this disease.

Thresholds: Soil *Verticillium*, root knot, and root lesion nematode counts, available from the Pest Diagnostic Clinic, University of Guelph, will help determine the need for control measures (see Appendix G, *Diagnostic Services*, on page 233).

Management Notes: Follow a 4–6-year rotation away from all related crops (tomatoes, potatoes, peppers). Cultivars vary in tolerance to verticillium wilt. Soil fumigation may be required if *Verticillium* and nematode counts are high. Nightshade and other solanaceous weeds also harbour this disease. Good weed control throughout the rotation is an important part of verticillium wilt control.

ANTHRACNOSE AND EARLY BLIGHT

Anthracnose and early blight are occasional diseases of eggplant. For identification, period of activity and management information, see the sections *Anthracnose,* on page 199, and *Early Blight*, on page 200. See also Table 9–43, *Eggplant Disease and Insect Control Recommendations*, on page 117.

PHOMOPSIS BLIGHT

This disease causes circular, brownish spots on leaves and fruit. Black spots (pycnidia) develop in the centres of the lesions. Fruit lesions enlarge to 5–8 cm (2–3 in.) in diameter. Avoid planting in infested fields for 3 years.

Table 9–42.
Greenhouse Eggplant Transplant Production Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate	Notes
DAMPING OFF, ROOT ROT (SOIL DRENCH TREATMENT)				
pthalamide (group M3)	captan	Maestro 80 DF	1.25 kg/1,000 L of water. Apply 50–85 L of solution per 100 m² (1,076 ft²).	48-hr re-entry.
		Supra Captan 80 WDG	1.25 kg/1,000 L of water. Apply 50–85 L of solution per 100 m² (1,076 ft²).	48-hr re-entry.
dithiocarbamate (group M2)	oxine benzoate	No-Damp	10 mL/L of water	Damping off.

Table 9–43.
Eggplant Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
ANTHRACNOSE AND EARLY BLIGHT						
QoI (group 11)	pyraclostrobin	Cabrio EG	0.56–1 kg	224–400 g	0	The high rate will also control late blight. Do not make more than 2 applications before rotating to a different fungicide group.
carboxamide (group 7)	boscalid	Lance WDG	175–315 g	70–126 g	0	**Early blight only.** Maximum 5 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 4-hr re-entry.
COLORADO POTATO BEETLE						
Transplant Treatment						
neonicotinoid (group 4)	imidacloprid	Admire 240 F	7–10 mL per 100 m of row	2–3 mL per 100 ft of row	70	Maximum 1 application/yr. Do not follow transplant treatments with a foliar Admire application. 24-hr re-entry.
Foliar Treatments						
neonicotinoid (group 4)	imidacloprid	Admire 240 F	200 mL	80 mL	7	Do not use foliar applications following transplant treatments. 24-hr re-entry.
carbamate (group 1A)	carbaryl	Sevin XLR	1.25 L	0.51 L	2	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1–2.25 kg	0.4–0.9 kg	2	
		Thiodan 4 EC	1.5–2.75 L	0.6–1.1 L	2	
		Thionex 50WP	1.1 kg	0.44 kg	2	
naturalyte (group 5)	spinosad	Entrust 80 W	50 g	20 g	1	Maximum 3 applications/yr. Maintain a spray water pH of 6 or greater.
		Success 480 SC	83 mL	34 mL	1	
FLEA BEETLES AND APHIDS						
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0–2.25 kg	0.4–0.9 kg	2	
		Thiodan 4 EC	1.5–2.75 L	0.6–1.1 L	2	
		Thionex 50WP	1.1 kg	0.45 kg	2	
carbamate (group 1A)	carbaryl	Sevin XLR	2.5 L	1.0 L	2	Flea beetles only.
TARNISHED PLANT BUG						
organophosphate (group 1B)	dimethoate	Cygon 480	500–700 mL	200–280 mL	7	
		Lagon 480 E	500–700 mL	200–280 mL	7	

[1] PHI = Pre-Harvest Interval.

Insects

CUTWORMS, TARNISHED PLANT BUG, WIREWORMS, APHIDS

For identification and management information on these common vegetable insects affecting eggplant, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–43, *Eggplant Disease and Insect Control Recommendations*, above.

COLORADO POTATO BEETLE

Identification: Adults are orange with 10 black stripes on the wings. Larvae are red-to-orange with two rows of black spots along their sides.

Period of Activity: Beetles are present all season. However, feeding damage is a larger concern early in the season when plants are small.

Thresholds: None established. Chemical controls are most effective when they are applied to small larvae.

Management Notes: Rotate away from solanaceous crops. Colorado potato beetle overwinter in the fields of host crops. Avoid planting eggplant adjacent to fields that had host crops the previous year.

If scouting indicates a need, apply insecticide as a border spray or full treatment. In-furrow transplant water treatments are also available. See Table 9–43, *Eggplant Disease and Insect Control Recommendations*, on page 117.

Warning

In a number of areas, Colorado potato beetles have developed a strong resistance to certain insecticides. To slow development of further resistance, it is essential for all growers to rotate between chemical groups each time a spray is applied.

FLEA BEETLES

Identification: Small, dark beetles cause "shot-hole" feeding damage on leaves.

Period of Activity: Begin monitoring for flea beetles as soon as the transplants are set in the field.

Thresholds: None established.

Management Notes: If beetles or feeding are found on the plants, apply one of the insecticides listed in Table 9–43, *Eggplant Disease and Insect Control Recommendations*, on page 117.

Nematode Control

See the section *Nematodes*, on page 63, for nematode control recommendations.

Harvest and Storage

Fruits should be harvested when they have reached marketable size but before the seeds begin to change colour. Fruits should be glossy and firm, not soft and spongy. Harvest by cutting the fruit from the plant. Handle carefully, as eggplant fruit bruises easily.

Store at 8°C–12°C (46°F–54°F) and a relative humidity of 90%–95% for up to one week.

GARLIC

Production Requirements

Garlic produces good yields on well-drained, deep, fertile soils. Extremely heavy soil types should be avoided. Low pH soils (5.0–5.5 or less) will result in very poor yields and plant stands. Garlic is a winter annual, planted in fall and harvested the following summer. Harvest begins when the leaf tops begin to dry, discolour and bend towards the ground.

Average Yields

Crop	per acre	per hectare
Garlic	2,000–4,000 lb	2,000–4,500 kg

Cultivars

Cultivated garlic plants do not produce true seed. All garlic is propagated vegetatively. Two types of garlic are grown in Ontario and are described as either "hardneck," which produce seed stalks, or "softneck," which do not.

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. Consult the Garlic Growers Association of Ontario for seed sources (www.garlicgrowers.on.ca). See also Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding and Spacing

The optimum planting date is from September to late October, with October 15 being ideal most years. To estimate the planting date, use the average date for the first fall frost for the area in which garlic is to be grown and begin planting on this date. See Table 4–1, *Average Frost-Free Period in Climatic Zones of Ontario (1961–90)*, on page 31.

	Metric	Imperial
Row spacing:	20 cm	8 in.
In-row spacing:	7–12 cm	3–5 in.
	Use wider spacing in lighter, drought-prone soils.	
Rate:	700–1,000 kg/ha	630–900 lb/acre
Depth of planting:	3–5 cm	1–2 in.
	between soil surface and top of clove	

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

On mineral soils, a total of 110 kg N/ha (99 lb/acre) is required. Apply half the nitrogen as soon as the garlic plants begin to grow in the spring. Apply the rest of the nitrogen in 2–3 side-dresses at 3-week intervals.

On muck soils, apply a total of 120 kg N/ha (107 lb/acre). Apply 90 kg/ha (80 lb/acre) prior to spring growth and the remainer as a side-dress application when the plants are 8–10 cm (3–4 in.) tall.

Phosphorus

Phosphorus requirements for garlic are similar to onions. Where the soil test values are 61 mg P per L soil (ppm) or higher, onions and garlic are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Potassium requirements for garlic are similar to onions. Where the soil test values are 181 mg K per L soil (ppm) or higher, onions and garlic are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Amend soil pH, phosphorus and potassium levels in the fall, prior to planting.

Irrigation

Garlic is shallow-rooted and sensitive to moisture stress. For most soil types, approximately 2.5 cm (1 in.) of water is required per week. On very coarse, sandy soils, as much as 5.0 cm (2 in.) is required weekly. For more information on irrigation scheduling, see Chapter 3, *Water Management*, on page 27.

Table 9–44.
Garlic Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
PENICILLIUM OR GREEN MOULD DISEASE						
dicarboximide (group 2)	iprodione	Rovral	4 g/L of water			Dip cloves into the Rovral suspension for 30 minutes immediately before planting.
BOTRYTIS, DOWNY MILDEW						
carboxamide + QoI (group 7 + 11)	boscalid + pyraclostrobin	Pristine WG	1.0–1.3 kg	0.4–0.52 kg	7	Use high rate for suppression of downy mildew. Maximum 6 applications/yr. Do not make sequential applications. 3-day re-entry interval.
QoI (group 11)	pyraclostrobin	Cabrio	0.84 kg	0.33 kg	7	**Downy mildew only.** Maximum 3 applications/yr.
biological	*Bacillus subtilis*	Serenade Max	3–4.5 kg	1.2–1.8 kg	0	**Botrytis** Begin applications at the first sign of disease or when conditions favour disease development.
			3–6 kg	1.2–2.4 kg	0	**Downy mildew** Begin applications at the first sign of disease or when conditions favour disease development.
ALLIUM WHITE ROT						
chlorophenyl (group 14)	dicloran	Botran 75 W	6.75–11.0 kg	2.7–4.4 kg		Spring Planting Apply 1–2 weeks prior to planting and work into top 4 cm (1.5 in.) of soil.
			36.0–44.0 kg	14.4–17.6 kg		Fall Planting Apply 1–2 weeks prior to planting and work into top 4 cm (1.5 in.) of soil.
APHIDS, THRIPS						
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	188 mL in 500 L water	75.2 mL in 45 gal water	14	**Thrips only.** Do not use more than 3 times/yr. 24-hr re-entry.
organophosphate (group 1B)	malathion	Malathion 500 E	1.1–2.75 L	0.44–1.1 L	3	
ONION MAGGOT						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	3.5 L in 1,000 L of water	1.4 L in 90 gal of water	50	Apply as a drench over the row on newly emerged plants (in the spring). 24-hr re-entry.
		Pyrinex 480 EC	3.5 L in 1,000 L of water	1.4 L in 90 gal of water	50	

[1] PHI = Pre-Harvest Interval.

Integrated Pest Management

Seed Treatments

Many garlic seed treatments intended for crop protection and disease reduction have been tested; however, none have provided consistent results. Healthy, damage-free and disease-free planting stock is the best defence against damping-off and root rots.

For more information on damping-off and root rots, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59.

Diseases

PENICILLIUM DECAY, GREEN MOULD

Identification: Infected cloves may fail to emerge in the spring or may produce weak, stunted plants that soon die. The fungus frequently sporulates on the surface of decaying cloves, producing bluish-green masses of spores.

Period of Activity: The fungus attacks cloves in late fall and early spring, prior to emergence.

Thresholds: None established.

Management Notes: Plant clonal cultivars known to be vigorous under Ontario growing conditions. Avoid damaging the seed cloves, especially during the cracking procedure. Many mechanized cracking devices cause excessive amounts of clove damage.

See Table 9–44, *Garlic Disease and Insect Control Recommendations*, on page 120.

FUSARIUM BASAL ROT AND ALLIUM WHITE ROT

See the sections *Fusarium Basal Rot*, and *Allium White Rot*, on page 137. Allium white rot control options are listed in Table 9–44, *Garlic Disease and Insect Control Recommendations*, on page 120.

Insects

WIREWORMS

For identification and management information on wireworms affecting garlic, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59.

LEEK MOTH

Identification: In Eastern Ontario and Quebec, leek moth damage has been recorded in garlic fields. The larvae tunnel mines and create pinholes in the leaf tissue and the scapes, sometimes causing distortion. They occasionally attack the bulb and stem. Damage to garlic cloves may predispose them to secondary bacterial or fungal diseases.

Larvae are yellowish-green with eight small, greyish spots on each segment and a pale-brown head capsule. They reach 13–14 mm (1/2 in.) at maturity. The reddish-brown pupa is encased in a loosely netted cocoon. These cocoons are usually found on the leaves.

Period of Activity: There are three generations per summer, the first in June, the second in July and the third in late August. Information from Europe indicates the insect overwinters as an adult moth in various sheltered areas (buildings, hedges, plant debris, etc.). They emerge in the spring when temperatures reach 9.5°C (49°F).

Management Notes: At present, there are no registered pest control products in Canada for the management of leek moth. Insecticide applications used to control other crop pests (thrips) may also reduce leek moth damage.

ONION THRIPS AND ONION MAGGOTS

See the sections *Onion Thrips*, and *Onion Maggot*, on page 138. Control options are listed in Table 9–44, *Garlic Disease and Insect Control Recommendations*, on page 120.

Nematodes (Bulb and Stem)

Identification: This is a microscopic plant parasitic nematode that generally enters plant material through the roots or wounds on the bulb/clove; however, research has shown that they can leave the soil under high humidity conditions and enter the stem or leaves close to the soil surface. Once in/on a suitable host, it injects a toxin into the plant as it feeds, causing lesions and resulting in distorted growth.

Period of Activity: The bulb and stem nematode becomes active in the spring with damage symptoms generally appearing mid-July through harvest.

Thresholds: 100 nematodes/kg of soil.

Management Notes: The key to management of this pest is prevention. Prevention includes planting clean seed and planting into clean ground. Test your soil before planting, use clean seed, and follow a 3-year rotation with non-host crops. Once in the soil, the pest can be spread though irrigation water, on contaminated seed, equipment, humans and animals.

For nematode control information, see the section *Nematodes*, on page 63, and Table 8–1, *Nematodes Impacting Vegetable Crops in Ontario*, on page 63.

Harvest and Storage

Harvesting begins when the leaf tops begin to dry, discolour and bend towards the ground. Another indication of bulb maturity is the reduced thickness of the sheath leaves surrounding the bulb.

For maximum storage life (5–8 months), garlic should be properly cured and stored at 0°C (32°F) and 60%–70% relative humidity. Higher humidity promotes the development of *Penicillium* and undesirable root growth. As storage temperatures are increased above 0°C (32°F), the rate of bulb weight loss increases.

For further information, consult the OMAFRA Factsheet, *Garlic Production*, Order No. 97-007.

HERBS

Production Guidelines

Herbs are a diverse category of plants. Optimum production requirements will vary, depending on the plant itself and its use in the marketplace. Adequate light, water and soil nutrients are essential. Most herbs prefer well-drained soil in a warm, sunny location. Heavy clay soils are generally not suitable.

Planting density, row width, weed control and fertilizer decisions are made based on the size of the roots and foliage, the market requirements and equipment limitations. Select disease-free and weed-free planting sites. Consider including heavy metals in the preplant soil analysis. See Table 9–45, *Culinary Herb Production Guidelines*, below.

Table 9–45.
Culinary Herb Production Guidelines

Crop	Type	Parts Used	Expected Yield kg/ha/yr	Soil pH	Light	Special comments
Anise	A	seed	500 to 900 (S)	6.0–7.5	FS	Seed when soil is 21˚C. Irrigate frequently until seed formation. Needs 130 days frost-free.
Borage	A	leaves, flowers, seeds, oil	322 (D FL)	5.0–8.0	FS–PS	Needs regular irrigation. Seeds shatter easily when swathed.
Caraway	B	leaves, roots, seeds, oil	1,500–3,000 (S)	6.0–7.5	FS	Mature seed shatters easily.
Chervil	B	leaves	9,700 (F)	7.0–8.0	FS–PS	May need protection from the wind. Does not transplant well.
Chives	HP	leaves, flowers	9,000–19,000 (F)	6.0–8.0	FS–PS	Do not plant more than 3 successive seasons in the same location.
Coriander/ cilantro	A	leaves, seeds, oil	1,500–2,000 (S) 9,000–12,000 (F)	6.5–7.5	FS PS (cilantro)	Hot weather induces flowering in cilantro. Does not transplant well.
Dill	A	leaves, seeds, oil	3,000–5,000 (F) 1,000–1,200 (S)	5.6–6.5	FS	Can be invasive. Prefers cool growing conditions. May require windbreaks.
Fennel	A	leaves, stems, roots, seeds, oil	14,000 (F) 1,000–1,500 (S)	7.0–8.0	FS–PS	Will hybridize with dill. Prefers low organic matter.
Lavender	HP	flowers, leaves, herb	2,900 (F FL) 300 (D FL)	6.5–7.5	FS	Must be vegetatively propagated for consistent quality.
Lemon verbena	TP	leaves, oil	Unknown	6.5	FS	High soil fertility will decrease flavour. Keep in pots 2 years before setting out.
Mint	HP	leaves, oil	9,000–19,000 (F) 1,000–2,000 (D)	6.5–7.0	FS	Highly invasive. Rotate with a small grain every 3 years.
Oregano	HP	tops of plant	9,000–19,000 (F) 1,000–2,000 (D)	6.0–7.0	FS	Renovate every 3–5 years.
Parsley	B	leaves, flowers, roots	10,000–20,000 (F) 1,000–2,000 (D)	6.0–7.0	FS–PS	Does not transplant well.
Rosemary	TP	leaves, oil	3,000 (F)	6.0–7.0	FS	Will not overwinter in the field.
Sage	HP	leaves, vegetative tops	24,000–38,000 (F) 4,800 (D)	6.0–6.5	FS	Must be vegetatively propagated for consistent quality.
Summer savory	A	leaves, flowering tops	900–1,500 (D)	6.0–6.5	FS	May need irrigation until established.
Sweet basil	A	leaves	14,000 (F) 1,400 (D)	6.0–7.0	FS	Sensitive to frost. Transplants well.
Sweet marjoram	A	tops of the plant, leaves, oil	4,000–9,000 (F) 300–500 (D)	6.5–7.5	PS until established, then FS	Yields decrease as planting ages.
Tarragon	HP	leaves	29,000 (F)	6.5	FS	Does not set seed.

Type: A = annual B = biennial HP = hardy perennial TP = tender perennial
Expected Yield: F = fresh FL = flowers D = dried S = seeds
Light: S = sun FS = full sun PS = partial shade

Table 9–46.
Planting Rates and Spacing Guidelines for Culinary Herbs

Herb	Propagate	Rate	Depth	Row Spacing	In-Row Spacing
Anise[1]	seed	12–16.5 kg/ha (10.7–14.7 lb/acre)	1 cm (½ in.)	45–75 cm (18–30 in.)	15–20 cm[1] (6–8 in.[1])
Borage	seed	12 kg/ha (10.7 lb/acre)	1.5–2 cm (½–¾ in.)	15–17 cm (6–7 in.)	5–6 cm (2–2.5 in.)
Caraway	seed	10 kg/ha (9 lb/acre)	2.5–4 cm (1–1½ in.)	25–30 cm (10–12 in.)	25–30 cm (10–12 in.)
Chervil	seed	15 kg/ha (13 lb/acre)	0.6 cm (¼ in)	30 cm (12 in.)	30 cm (12 in.)
Chives	seed	1.8 kg/ha (1.6 lb/acre)	0.6 cm (¼ in.)	30 cm (12 in.)	10 cm (4 in.)
Coriander/ cilantro	seed	15–20 kg/ha (13–18 lb/acre)	2.5–4 cm (1–1½ in.)	25–30 cm (10–12 in.)	7–10 cm (3–4 in.)
Dill	seed	9–11 kg/ha (8–10 lb/acre)	0.6 cm (¼ in)	Seed: 25–30 cm (10–12 in.) Herb: 54–61 cm (20–24 in.)	10 cm (4 in.)
Fennel	division	6.0 kg/ha (5.3 lb/acre)	0.6–1.3 cm (¼–½ in.)	30–40 cm (12–16 in.)	30 cm (12 in.)
Lavender	cuttings	100,000 plants/ha (40,000 plants/acre)	–	40 cm (16 in.)	25 cm (10 in.)
Lemon verbena	cuttings	10,000 plants/ha (4,000 plants/acre)	–	100 cm (40 in.)	100 cm (40 in.)
Mint	roots or cuttings	54,400 plants/ha (21,800 plants/acre)	–	60 cm (24 in.)	30 cm (12 in.)
Oregano	seed or division	43,500–109,000 plants/ha (17,400–43,600 plants/acre)	5–10 mm (¼–½ in.)	30–40 cm (12–15 in.)	30–40 cm (12–15 in.)
Parsley	seed	3–20 kg/ha (2.7–18 lb/acre)	6 mm (¼ in.)	30–50 cm (12–20 in.)	15–20 cm (6–8 in.)
Rosemary	cuttings	20,000–40,000 plants/ha (8,000–16,000 plants/acre)	–	50–100 cm (20–40 in)	50 cm (20 in.)
Sage	seed[2]	14–20 kg/ha (12–18 lb/acre)	0.13 cm (1⁄16 in.)	45 cm (18 in.)	25–30 cm (10–12 in.)
Summer savory	seed	30–35 seeds/m (9–10 seeds/ft)	1–2 cm (½–¾ in.)	30 cm (12 in.)	20 cm (8 in.)
Sweet basil	transplants	110,000 plants/ha (44,000 plants/acre)	–	30 cm (12 in.)	30 cm (12 in.)
Sweet marjoram	seed, cuttings	–	Cover lightly	30 cm (12 in.)	20–25 cm (8–10 in.)
Tarragon	division of root crowns	55,000–66,600 plants/ha (22,000–26,600 plants/acre)	–	50–60 cm (20–24 in.)	30 cm (12 in.)

[1] Thin anise plants to 30–40 cm (12–15 in.).

[2] Sage may also be propagated with cuttings, division and layering.

Propagation

There are three main propagation methods for herbs:

Seed: Sow directly in the field or into trays for transplanting. Most herbs perform poorly from bare root transplants. Not all herbs transplant well.

Cuttings: Take 8–10 cm (3–4 in.) cuttings from the tips of vegetative growth or from the stem. Remove leaves and buds from the bottom half of the cutting, dip in rooting hormone and stick into sterilized horticultural sand or vermiculite. Cover to keep humidity high.

Divisions: Division is usually performed in the spring. Divide crowns (the junction of the root and stem) into clumps. Cut rhizomes into nodes or root clusters that contain nodes. Separate bulbs into clusters.

See Table 9–46, *Planting Rates and Spacing Guidelines for Culinary Herbs*, above.

Table 9–47.
Herb Cabbage Looper Control Recommendations

Group	Common Name	Trade Name	Rate per hectare	Rate per acre	PHI[1]	Notes
Mints, celery seed, parsley (dried), mustard seed, nasturtium, basil, caraway, catnip, chervil (dried), coriander, dill and fennel						
biological (Group 11)	*Bacillus thuringiensis*	Dipel 2X DF	275–550 g	110–220 g	0	Apply to control small larvae. Maximum 5 applications/yr.
		Bioprotec CAF	1.4–2.8 L	0.56–1.1 L	0	

[1] PHI = Pre-Harvest Interval.

Integrated Pest Management

There are limited options for chemical pest control in herb crops. Pest control measures often include cultural practices aimed at prevention and elimination of the pest problem. For more information on general cultural practices impacting pest populations, see Chapter 7, *Integrated Pest Management*, on page 51.

Diseases

The most common diseases of herbs are leaf blights, root rots, nematodes and viruses.

Follow these guidelines to reduce the risk of disease in herbs:

- Practice good sanitation at all times. Remove infected crop debris from the field immediately.
- Sanitize all equipment that comes in contact with the plants before and after handling.
- Use resistant or tolerant strains where possible.
- Use rotational crops that reduce the population of diseases associated with the herb crop.
- Use cover crops that reduce nematode populations.
- Manage soil moisture to reduce the threat of water-loving soil pathogens.
- Encourage optimum air movement through the plants to reduce periods of leaf wetness.

Insects

Insect pests found in herbs vary greatly between the different crops. For cabbage looper control on a wide variety of herb crops, see Table 9–47, *Herb Cabbage Looper Control Recommendations*, above.

Follow these guidelines to reduce the risk of insect damage:

- Evaluate transplants for the presence of insects. Do not plant infested plants.
- Use resistant or tolerant varieties where possible.
- Maintain good weed control. Many weeds act as host crops for specific insects.
- Use physical barriers such as screens and row covers where appropriate.
- Hand pick or use high-pressure water sprays to dislodge insects.
- Many native insects act as predators and parasites of crop pests. Use border plantings that attract these beneficial insects. Plants that attract beneficials include alyssum, aster, chrysanthemum, cosmos, goldenrod, rudbeckia, spiraea, tansy, Queen Anne's lace, yarrow and zinnia.

Harvest and Storage

If practical, harvest in early morning after the dew has dried from the crop and before the sun dissipates the essential oils; leaves should be clean and free of dust and soil. Do not completely strip the stems of the entire leaf crop, as remaining leaves are necessary to keep the plants growing.

Anise

When seeds begin to turn grey, cut plants 10–12 cm above ground. Harvest seeds on main stem first. Swath and thresh after 4–5 days. Dry at 29°C–48°C (84°F–118°F) to 10%–12% moisture.

Borage

Borage flowers 60 days after seeding. Pick blossoms as they open. Swath when earliest and largest seeds are at the proper stage and the stems are still green. Dry at 32°C–48°C (90°F–118°F) in the dark to 9.5% moisture. Do not keep product longer than 1 year.

Caraway

Harvest when 75% of the seeds are brown. Combine to a height of 30–40 cm. Dry at 29°C–48°C (84°F–118°F) to 10% moisture. Store in aeration bin.

Chervil

Harvest leaves frequently to encourage growth. Fresh chervil is preferred by many markets. Dry at 29°C–43°C (84°F–109°F) to maintain colour.

Chives

Cut 6–7 cm above soil surface, up to 3–4 times per year. Fresh tips are sold 15–20 cm long. Remove any flower stems or wilted leaves. Flash freeze or freeze-dry for best quality.

Coriander/cilantro

Cut coriander when 40% of the fruit is ripe. Thresh 4–5 days later. Dry at ambient temperatures using aeration until 18% moisture. Finish drying at 80°C–90°C (176°F–194°F). Cut cilantro just before flowering. Refrigerate leaves immediately after harvest.

Dill

Harvest seeds 7–9 days after petal drop. Cut during a dew to reduce shattering. Harvest leaves just as the flowers open. Dry leaves at 32°C (90°F) to avoid browning. Pick umbels as plants flower and the seed is still green.

Fennel

Swath seeds when they are waxy-ripe and thresh 5–7 days later. Dry at 29°C–43°C (84°F–109°F) and separate seeds from stems after drying. Harvest flower stalks just before bloom and use fresh. Harvest leaves fresh throughout the season.

Lavender

Harvest flowers at full bloom for potpourri. Harvest flowers at the end of bloom for oil. Cut stems below the first set of leaves. Dry in the dark at temperatures below 32°C (90°F) to preserve colour.

Lemon Verbena

Harvest leaves before bloom. Strip leaves individually from the plants. Dry on screens at 32°C–48°C (90°F–118°F).

Mint

Leaves can be picked any time for fresh or dry market, up to 2 times per year. For fresh or dry market, harvest leaves individually or gather in bunches. Dry leaves at 37°C–40°C (99°F–104°F). For oil, pick just as flowering begins, swath and allow plants to wilt before processing.

Oregano

Harvest in the first year at the start of bloom. Cut plants at a 15–20 cm height, 2–4 times per year. Dry at 29°C–43°C (84°F–109°F).

Parsley

Begin harvest approximately 75 days after seeding. For fresh market, harvest manually and bunch. Wash and cool immediately to 0°C–2°C (32°F–35°F) and store at high relative humidity.

Rosemary

Cut when flowers begin to bloom. Never harvest more than half the plant. Dry at temperatures below 40°C (104°F) in a well-ventilated, dark area. Can also be freeze-dried.

Sage

Harvest leaves and tops in the fall. Cut above the woody portion of the stem. For oil, cut at full bloom. Separate leaves from stems immediately after harvest. Dry in a well-aerated area at 37°C (99°F).

Summer Savory

Cut just above the lowest branches, up to 2 times per year. Dry in the field after cutting. Screen dry material to remove sand.

Sweet Basil

Cut stalks just before flowering, leaving at least 4 sets of leaves. Harvest large fields twice a year, beginning at 80 days after planting. Dry for 2 weeks at ambient temperatures (preferably 29°C–48°C (84°F–118°F)). Leaves may turn brown at high temperatures.

Sweet Marjoram

Pick the leaves just as the first flowers open. For oil, harvest during flowering. Leave 10–12 cm of stubble for regrowth. Hang to dry at 54°C (130°F) to 14% moisture or freeze dry.

Tarragon

Cut in the first year when plants are 40–60 cm high. Two cuttings are possible in following years. Cut plants 15 cm above the ground. Dry leaves at 60°C (140°F).

For more information, see the OMAFRA Factsheet, *Growing Culinary Herbs in Ontario*, Order No. 02-049.

LETTUCE, ENDIVE & PARSLEY

Production Requirements

Lettuce, endive and parsley are cool-season vegetables. They grow best at temperatures between 13°C–18°C (55°F–64°F). On mineral soils, production is limited to the transplanted early crop and the seed-sown late crop. On muck soils, in cooler areas such as Bradford, leafy green crops may be produced throughout the growing season. The preferred soil pH is 6.1–6.5 on mineral soils and 5.5 on muck.

Average Yields

Crop	per acre	per hectare
Head lettuce (crisphead, butterhead)	800–1,000 cases (25,000–40,000 lb)	2,000–2,500 cases (28,000–45,000 kg)
Cos lettuce (romaine)	1,000–1,200 cases (25,000–40,000 lb)	2,500–3,000 cases (28,000–45,000 kg)
Leaf lettuce	12,000–16,000 lb	13,500–18,000 kg
Endive / escarole	12,000–16,000 lb	13,500–18,000 kg
Parsley	700–1,100 bushels	1,500–2,500 bu

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Planting, Seeding and Spacing

Germination occurs even at temperatures as low as 2°C (35°F) for lettuce and 4°C (40°F) for parsley. Germination is delayed at very high soil temperatures (>27°C or 81°F).

Use coated or pelleted seed with a precision seeder to ensure a more uniform stand. This also reduces thinning costs and provides higher percentages of cut at harvest time.

Seeding time is important on both muck and mineral soils. Immature plants will recover from a frost event. The wrapper leaves on mature heads are very susceptible to frost and can only be marketed at a lower grade if they are damaged.

Properly hardened transplants, when set in the field in the early spring, can tolerate temperatures as low as –7°C (19°F). See the section *Transplanting*, on page 39.

Plant approximately 1–2 kg of seed/ha (1.5 lb/acre). See Table 9–48, *Lettuce, Endive and Parsley Spacing and Seeding Rates*, right.

Table 9–48.
Lettuce, Endive and Parsley Spacing and Seeding Rates

	Metric (cm)		Imperial (in.)	
	Row Spacing	In-Row Spacing	Row Spacing	In-Row Spacing
Butterhead and leaf	30	20–30	12	8–12
Crisphead	40	30–35	16	12–14
Endive	40	20–30	16	8–12
Parsley	30–40	10–15	12–16	4–6

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

Broadcast and incorporate the recommended preplant nitrogen with the required potash and phosphate. On mineral soils, side-dress the remaining nitrogen 3 weeks after transplanting or thinning the crop. See Table 9–49, *Lettuce Nitrogen Recommendations*, below.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, lettuce crops on both muck and mineral soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Table 9–49.
Lettuce Nitrogen Recommendations

	Actual N	
Soil Type	kg/ha	lb/acre
Mineral soils		
Preplant broadcast	55	49
Side-dress	55	49
Total	**110**	**98**
Muck soils		
Preplant broadcast[1]	120	107

[1] Reduce to 100 kg/ha (107 lb/acre) for mid- to late-season plantings.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, lettuce crops on both muck and mineral soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, apply and incorporate them prior to planting.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

COPPER

Copper (Cu) deficiency may show up on organic (peat and muck) soils. Mix copper with the fertilizer and apply at 14–29 kg Cu/ha (12.5–25 lb/acre) on newly cultivated muck. Subsequent applications may be made every 2 or 3 years at about one-third the rate recommended for new muck. See the section *Copper*, on page 18, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

MANGANESE

Manganese-deficient lettuce shows marked yellowing between the veins, which remain dark green. Manganese deficiency usually shows up on slightly acid or alkaline muck, peat and dark-coloured sandy soils. Soil application is not recommended for manganese because of the large amounts required. If a deficiency is identified, apply foliar manganese sprays starting after thinning or transplanting. For more information, see the section *Manganese*, on page 19, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

CALCIUM

Under hot, dry conditions, lettuce may benefit from calcium to prevent tipburn symptoms. See the section *Calcium*, on page 15, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information, see the section *Plant Analysis*, on page 3.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–50, *Lettuce and Endive Nutrient Sufficiency Ranges*, below.

Table 9–50.
Lettuce and Endive Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts per Million (ppm)				
Endive												
Oldest undamaged leaf	8-leaf stage	4.5–6	0.45–0.8	4.5–6	2–4	0.25–0.6	–	–	15–25	30–50	25–35	5–10
	maturity	3.5	0.4–0.6	6	1.8–3	0.3–0.4	–	–	15–20	20–40	30–40	5–10
Head Lettuce												
Most recently mature	8-leaf stage	4–5	0.4–0.6	5–7	1–2	0.3–0.5	0.3–0.5	50–150	20–40	25–50	15–30	5–10
Wrapper leaf	heads half size	2.5–4	0.4–0.6	4.5–8	1.4–2	0.3–0.7	0.3–0.5					
	maturity	2–3	0.25–0.5	2.5–5	1.4–2	0.3–0.7	0.3–0.5					
Romaine Lettuce												
Oldest undamaged leaf	8-leaf stage	5–6	0.35–0.8	5–6	2–3	0.25–0.35	–	–	15–25	20–50	30–45	5–10
	maturity	3.5–4.5	0.35–0.6	5–6	2–3	0.25–0.4	–					

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*, 5th Edition. John Wiley & Sons, Inc. New York.

Table 9–51.
Lettuce Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Ridomil Gold 1G	metalaxyl-m	25 kg/ha (10 kg/acre)	damping-off, pythium stunt	Apply with seed in-furrow. Use 115 g per 100 m of row. Do not use on transplants.
Apron XL LS	metalaxyl-m	20–40 mL per 100 kg seed	pythium damping-off	**For use on imported seed only.**
Thiram 75 WP	thiram	90 g per 25 kg of seed	seed decay, seedling blight, damping-off	

Integrated Pest Management

See OMAFRA Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario,* for a comprehensive guide to IPM for lettuce.

Diseases

DAMPING-OFF AND ROOT ROTS

For more information on damping-off and root rots, see Chapter 8, on page 59. For lettuce crops, also see Table 9–51, *Lettuce Seed Treatments,* above.

BOTRYTIS GREY MOULD

Identification: White-to-grey downy fungi first develop on older, outer leaves. This rapidly reduces the leaf to a water-soaked, slimy mass of tissue and causes the plant to completely collapse.

Period of Activity: Grey mould overwinters in the soil and on plant debris. Rapid fungal growth occurs in damp weather with temperatures of 18°C–23°C (64°F–73°F).

Thresholds: None established.

Management Notes: Fungicides can be effective, but it is very difficult to get adequate coverage of the lower leaves, where infection first occurs. Grow on raised beds to increase air movement and decrease disease pressure. Follow a good crop rotation with cereals and other non-host crops. See Table 9–52, *Lettuce and Parsley Disease Control Recommendations,* on page 129.

DOWNY MILDEW

Identification: Infection usually begins on the mature leaves and spreads inward toward the central leaves. Chlorotic (yellowish) or pale-green areas appear on the upper surface of the leaves. White, velvety areas are found on the lower leaf surface. Infected tissue usually dies.

Period of Activity: The fungus overwinters in wild lettuce plants and on crop debris. Spores are spread by wind or splashing rain. For germination to occur, the leaf surface must be moist. This is a cool-season disease. The optimum temperature for infection occurs from 15°C–20°C (59°F–68°F). The time from infection to the production of new spores varies from 5–18 days.

Thresholds: None established.

Management Notes: Select resistant cultivars and follow a 2–3-year crop rotation. Plowing infected residue may reduce the soil inoculum. See Table 9–52, *Lettuce and Parsley Disease Control Recommendations,* on page 129.

LETTUCE DROP (SCLEROTINIA WHITE MOULD)

Identification: Lettuce drop (wilting of the entire plant) is most often observed as plants approach maturity. The limpness of the entire plant resembles the symptoms of grey mould. Cottony-white fungi develop on the underside of the lower leaves. Black sclerotia are often embedded within it.

Period of Activity: The long-lived sclerotia overwinter in the soil and on plant debris. Lettuce drop is most prevalent during cool, wet weather.

Thresholds: None established.

Management Notes: Follow a 2–3-year rotation with non-susceptible crops such as onions, beets or spinach. Good drainage and growing lettuce on raised beds improves drainage and increases air movement around the plants. Flooding infested land for 3–4 weeks causes the breakdown of sclerotia and may reduce soil populations. Table 9–52, *Lettuce and Parsley Disease Control Recommendations,* on page 129.

SEPTORIA LEAF SPOT

Identification: Greyish-brown spots with yellow margins appear on leaves and petioles. Small, black specks (pycnidia) are often noticable in the centre of the lesions.

Period of Activity: Septoria is spread by infected seed, crop residues and on weed hosts. Spores germinate at

Table 9–52.
Lettuce and Parsley Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
BOTRYTIS GREY MOULD						
Greenhouse-grown seedlings						
dithiocarbamate (group M3)	ferbam	Ferbam 76 WDG	2 kg/ 1,000 L water	0.8 kg/ 9 gal water		**Lettuce only.** Spray seedlings before transplant.
Field application						
dicarboximide (group 2)	iprodione	Rovral	1.5 kg	0.6 kg	4	**Lettuce only.** Maximum 4 applications/yr. Start after thinning, apply at 7-day intervals. 12-hr re-entry.
carboxamide (group 7)	boscalid	Lance WDG	285 g	114 g	14	**Lettuce only.** Maximum 2 applications/yr. 4-hr re-entry.
DOWNY MILDEW						
phenylamides + dithiocarbamate (group 4 + M3)	metalaxyl-M + mancozeb	Ridomil Gold MZ 68 WP	2.5 kg	1 kg	14	**Lettuce only.** Maximum 3 applications/yr.
dithiocarbamate (group M3)	zineb	Zineb 80 W	1.7–2.3 kg	0.68–0.92 kg	10	**Lettuce only.**
phosphonate (group 33)	fosetyl-al	Aliette WDG	2.8 kg	1.12 kg	7	**Lettuce only.** Maximum 5 applications/yr. 12-hr re-entry.
biological	*Bacillus subtilis*	Serenade Max	3–6 kg	1.2–2.4 kg	0	Begin applications at the first sign of disease or when conditions favour disease development.
LETTUCE DROP (SCLEROTINIA WHITE MOULD)						
dicarboximide (group M3)	vinclozolin[2]	Ronilan EG	1.1 kg	0.44 kg	28	**Lettuce only.** 12-hr re-entry. Maximum 3 applications/yr.[2]
carboxamide (group 7)	boscalid	Lance WDG	385 g	154 g	14	Maximum 2 applications/yr. 4-hr re-entry.
chlorophenyl (group 14)	dicloran	Botran 75 W	2.3–3.75 kg	0.9–1.5 kg	14	**Lettuce only.** Maximum 2 applications/yr.
biological	*Bacillus subtilis*	Serenade Max	3–6 kg	1.2–2.4 kg	0	Begin applications at the first sign of disease or when conditions favour disease development.

[1] PHI = Pre-Harvest Interval.

[2] Apply 12 days after thinning on seeded crop or 5–7 days after transplanting. Second and third applications may be made at 10-day intervals. Note that a 15-m buffer zone must be maintained between sprayed areas and aquatic systems such as ponds and ditches.

temperatures above 12°C (54°F). Infection requires the presence of water or high humidity (greater than 90% relative humidity) for 24 hr.

Management Notes: Seed-borne infections decrease in 2-year-old (or older) seed. Bury infected crop residues and follow a 2–3-year rotation to reduce soil-borne infections.

RHIZOCTONIA BOTTOM ROT

Rust-coloured sunken lesions appear on the midrib of lower leaves. Bottom rot is most commonly observed on mineral soils. The fungus is active during warm, humid weather. Rotate with legumes, cereals, grasses or other non-host crops. Plant in areas with good soil drainage and avoid fields with a history of bottom rot. Growing lettuce on raised beds will improve air circulation near the base of the plant, where infection is likely to begin.

CORKY ROOT ROT

Yellow lesions appear on the roots. These lesions enlarge until the entire tap root is brown, rough and cracked. This disease builds up with continual lettuce cropping. It can also be caused by excess nitrogen. Corky root rot is more severe in warm conditions and in summer and fall crops.

Allow sufficient time between lettuce crops for the plant residues to decompose completely. Avoid applying excessive amounts of nitrogen, especially urea. Raised beds and reduced irrigation are recommended to encourage deep rooting. Resistant cultivars are available.

BACTERIAL WILT, DRY LEAF SPOT

Bacterial wilt is a seed-borne pathogen. Water-soaked, wedge-shaped spots form along the leaf margins. Spots may become olive coloured. Bacterial wilt requires a wound, such as frost injury, sand blasting or mechanical

Table 9–53.
Lettuce and Parsley Aphid Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
At-Planting Treatments						
neonicitinoid (group 4)	imidacloprid	Admire 240 F Alias 240 EC	10.2 mL per 1,000 plants		21	Transplant tray plug drench. Do not follow transplant drench with soil or foliar treatments. 24-hr re-entry.
		Admire 240 F Alias 240 EC	650 mL	260 mL	21	Soil application (field drench). Apply in 2,000 L water/ha (180 gal/ acre) directly over the row. Do not follow soil drench application with foliar treatments. 24-hr re-entry.
Foliar Treatments						
neonicitinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	22.4–34.4 g	7	Also controls pea leafminer. Maximum 5 applications/yr. Alternate applications with other insecticide families. 12-hr re-entry.
	imidacloprid	Admire 240 F Alias 240 EC	200 mL	80 mL	7	Maximum 2 applications per crop. Do not make a foliar imidacloprid application following a plug treatment or soil drench application. 24-hr re-entry.
carbamate (group 1A)	pirimicarb	Pirimor 50 DF	300–500 g	120–200 g	7	**Lettuce only.** 24-hr re-entry.
chlorinated cyclodiene (group 2 A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	**Head lettuce only.** Maximum 3 applications/yr.
		Thionex 50WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.44 kg	7	**Head lettuce only.** Maximum 4 applications/yr.
	diazinon[5]	Diazinon 500 E	1.1 L	0.44 L	10	**Lettuce only.**
					14	**Parsley only.**
	dimethoate	Cygon 480	700 mL	280 mL	7	**Leaf lettuce only.** Do not use on head lettuce.
	methamidophos	Monitor 480	1.1–2.25 L	0.44–0.9 L	14	**Head lettuce only.** 48-hr re-entry.
	naled[2]	Dibrom	1.1–1.65 L	0.44–0.66 L	4	**Lettuce, endive only.**

[1] PHI = Pre-Harvest Interval.

[2] Control of aphids with naled and diazinon has been inconsistent in many areas.

damage, to infect healthy plants. Excessive nitrogen or overhead irrigation may increase disease levels. Follow good sanitation practices in all greenhouse areas used for transplant production.

LETTUCE MOSAIC VIRUS

Leaves develop chlorotic, yellow spotting. Plants grown from infected seed or infected early in their development have pale green-to-yellow mottled leaves. Lettuce mosiac is primarily seed-borne. However, it can also be transmitted by aphids.

Mosaic-indexed or mosaic-tested seed is available from most sources. This seed is produced in special areas where it is carefully checked to ensure that it is virtually free from seed-borne mosaic. Control aphids, which spread the disease from infected lettuce plants. Weeds such as groundsel, shepherd's-purse and lamb's-quarters are alternate hosts.

ASTER YELLOWS

Transmitted by the aster leafhopper, aster yellows causes a bright yellowing and twisting of leaves. Infected crisphead types suffer poor head formation. Secondary bacterial rots often follow aster yellows. See the section *Aster Leafhopper*, on page 97, for control recommendations.

Insects

APHIDS, CUTWORMS, TARNISHED PLANT BUG

For identification and management information on these common vegetable insects affecting lettuce, endive and parsley, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, Table 9–53, *Lettuce and Parsley Aphid Control Recommendations*, above, and Table 9–54, *Lettuce, Endive and Parsley Insect Control Recommendations*, on page 131.

Table 9–54.
Lettuce, Endive and Parsley Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
CUTWORMS						
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	83 mL	33 mL	3	**Head lettuce only.** 24-hr re-entry. Maximum 3 applications/yr. Dark-sided and white cutworms only.
	cypermethrin	Ripcord 400 EC	175 mL	70 mL	21	Do not disturb soil for 5 days after treating.
	permethrin	Pounce	180–390 mL	72–156 mL		Apply up to the 5-leaf stage. Do not disturb soil for 5 days after treating. Use high rates on muck soils.
ASTER LEAFHOPPER						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	125 mL	50 mL	14	**Lettuce only.** Maximum 4 applications/yr.
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	5	Head lettuce.
					21	Leaf lettuce, endive, parsley.
organophosphate (group 1B)	malathion	Malathion 500 E	1.5–2.75 L	0.6–1.1 L	3	Head lettuce.
					14	Leaf lettuce.
PEA LEAFMINER						
neonicitinoid (group 4)	acetamiprid	Assail 70 WP	86 g	34 g	7	Maximum 5 applications/yr. Do not apply more than once every 7 days. 12-hr re-entry.
cyromazine (group 17)	cyromazine	Citation 75 WP	188 g in 200 L water	75 g in 18 gal water	7	Maximum 5 applications/yr. 12-hr re-entry interval. See the label for a full list of leafy greens this product is registered for.
TARNISHED PLANT BUG						
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	83 mL	33 mL	3	**Head lettuce only.** Maximum 3 applications/yr. 24-hr re-entry. See the label for a full list of leafy greens this product is registered for.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	**Head lettuce only.**
carbamate (group 1A)	carbaryl	Sevin XLR	2.5–5.25 L	1–2.1 L	5	Head lettuce.
					21	Leaf lettuce, endive, parsley.
CABBAGE LOOPER						
biological (group 11)	*Bacillus thuringiensis*	Dipel 2XDF	275–550 g	110–220 g	0	**Lettuce & parsley only.** 275 g/ha rate maximum for parsley.
		Thuricide HPC	2.0–4.25 L	0.8–1.7 L	0	**Lettuce only.**
naturalyte (group 5)	spinosad	Success 480 SC	182 mL	73 mL	1	Maximum 3 applications/yr. Maintain a spray pH of 6 or greater. See the label for a full list of leafy greens this product is registered for.
		Entrust 80 W	109 g	44 g	1	
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	83 mL	33 mL	3	**Head lettuce only.** Maximum 3 applications/yr. 24-hr re-entry.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	**Head lettuce only.** Maximum 3 applications/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	14	
carbamate (group 1A)	methomyl	Lannate	0.51–1.0 kg	0.2–0.4 kg	7	**Lettuce only.** 24-hr re-entry.
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.44 kg	7	**Head lettuce only.** Maximum 4 applications/yr.
	methamidophos	Monitor 480	1.1–2.25 L	0.44–0.9 L	14	**Head lettuce only.** 48-hr re-entry.
	naled	Dibrom	1.1–1.65 L	0.44–0.66 L	4	**Lettuce & endive only.**

[1] PHI = Pre-Harvest Interval.

ASTER LEAFHOPPER

The aster leafhopper transmits aster yellows. See the aster yellows (AYI) calculation in the section *Aster Leafhopper*, on page 97.

Treat when the AYI equals 20–25 for head lettuce or 30–35 for romaine. See Table 9–54, *Lettuce, Endive and Parsley Insect Control Recommendations*, on page 131.

PEA LEAFMINER

The pea leafminer (PLM) has been found in the Holland Marsh area of Ontario. Larvae feed between the upper and lower surface of the leaves, reducing photosynthetic capacity. The mines also affect marketability and provide an entrance for disease organisms. Leafminers are most likely to attack head and leaf lettuce types. For more information, see the section *Leafminers*, on page 104. See Table 9–54, *Lettuce, Endive and Parsley Insect Control Recommendations*, on page 131.

CABBAGE LOOPER

While this is a rare problem, the cabbage looper can cause sporadic damage in lettuce, endive and parsley. Use a 5% infestation control threshold. See Table 9–54, *Lettuce, Endive and Parsley Insect Control Recommendations*, on page 131.

Nematode Control

See the section *Nematodes*, on page 63, for nematode control recommendations.

Harvest and Storage

Lettuce and leafy green crops are usually harvested by hand and packed into cartons in the field. Mechanical harvesters are now available.

Leafy green crops are not adapted to long-term storage. To achieve a 2–3-week storage life, maintain a temperature of 0°C (32°F) and 95%–100% relative humidity. Vacuum cooling or hydrocooling can help maintain a fresh appearance. Cracked ice used in or around packages will help maintain quality during transportation.

For more information on storage, see Chapter 6, *Food Safety and Storage*, on page 45.

For more information on pest management in leafy green crops, consult the following OMAFRA Factsheets and publication:

- *The Aster Leafhopper and Aster Yellows*, Order No. 98-057
- *Aphids Infesting Lettuce and Celery in Ontario*, Order No. 00-053
- *Leafminers Attacking Field Vegetables and Greenhouse Crops*, Order No. 00-039
- *Caterpillar Pests of Crucifer Crops*, Order No. 99-035
- *Tarnished Plant Bug Damage on Vegetable Crops in Ontario*, Order No. 98-025
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*

ONIONS, LEEKS & SHALLOTS

Production Requirements

Allium species (onions, leeks, shallots, chives, etc.) grow in a wide range of soil types. They tend to grow best on mineral soils with a pH range of 5.8–7.0 and on muck soils with a pH range of 5.0–6.0. Alliums mature in 75– 120 days.

Average Yield

Crop	per acre	per hectare
Dry onions (cooking, Spanish)	600–1,000 #50 bags	1,500–2,500 #50 bags
Bunching (green) onions	900–1,200 lb (4,000 dozen)	1,000–1,500 kg (10,000 dozen)
Leeks	500 cases[1]	1,250 cases[1]
Shallots	9–12 tons	20–27 tonnes

[1] 1 case = 24 bunches of 3 leeks each

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

In Ontario, both summer and autumn leeks are grown. Two types of shallots are generally available: the French-Italian (brownish-red skin), the most commonly grown, and the Welsh shallot (green shallot).

Spacing and Seeding

The minimum soil temperature for seed germination is 2°C (35°F). Ideal planting conditions occur when the soil temperatures reach 10°C (50°F). The optimum planting depth ranges from 0.5–2.5 cm ($^{1}/_{4}$–1 in.). Use shallow seeding on heavy mineral or crust-prone soils. In drier soil and in areas where wind and water erosion are problems, sow seeds at a depth of 3–4 cm (1$^{1}/_{4}$–1$^{1}/_{2}$ in.).

To achieve an earlier crop, dry bulb onions can be grown in plug trays and transplanted into the field when soil conditions permit. Transplants have some advantages in managing disease and weeds, as well as producing an earlier crop. See the section *Transplanting*, on page 39. See Table 9–55, *Allium Species Spacing and Seeding Rates*, below.

Irrigation

Allium species have shallow, limited root systems. The critical water-use period lasts up to, and including, the bulb formation stage. When overhead irrigating, do not permit the available soil water to fall below 60%. For drip-irrigated onion crops, use an irrigation threshold of 85% available soil water. The plants should receive 2.5 cm (1 in.) of water a week, either as rainfall or irrigation. Irrigation after bulb maturity may not be beneficial and may reduce yield and/or quality.

Irrigation may not be necessary on deep muck soils. Maintain the water table at 85 cm (2.5 ft) below the soil surface.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

On shallow muck soil or soils with a high proportion of mineral soil, band 200 kg/ha (180 lb/acre) monoammonium phosphate (MAP), applied 5–7.5 cm (2–3 in.) below the seed. Reduce the broadcast fertilizer by 22 kg/ha (20 lb/acre) nitrogen and 96 kg/ha (86 lb/acre) phosphate.

Table 9–55.
Allium Species Spacing and Seeding Rates

	Metric			Imperial		
Crop	Row Spacing (cm)	In-Row Spacing (cm)	Rate (kg/ha)	Row Spacing (in.)	In-Row Spacing (in)	Rate (lb/acre)
Dry bulb (cooking and Spanish)	35–43	2.5–3.5	4–4.5	14–17	1–1.5	3.5–4
Bunching (green)	30–38	1–2.5	7	12–15	0.5–1	6
Dry bulb transplants (cooking and Spanish)	35–43	10–12.5	1.7–3.5[1]	14–17	4–5	1.5–3[1]
Leeks (transplants)	60–90	10–15	1.1–2.2[1]	24–35	4–6	1–2[1]
Pickling onions			35–45			31–40
Shallots	46–60	7.5–10	220–330[2]	18–24	3–4	200–300[2]

[1] Listed seeding rates will produce enough transplants for 1 ha (1 acre).

[2] Bulbs.

Table 9–56. Onion Nitrogen Recommendations

Soil Type	Actual N	
	kg/ha	lb/acre
Mineral Soils		
Apply up to	110	98
Muck Soils		
Preplant	90	80
Side-dress	30	27
Total	**120**	**107**

Leeks require higher amounts of nitrogen than onions, normally around 200 kg N/ha (180 lb/acre), applied in three instalments: one preplant and two side-dressings.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, onions grown on both muck and mineral soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, onions grown on both muck and mineral soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

COPPER

Copper deficiency occurs on organic (peat and muck) soils. Bulbs show poor-coloured skins. Copper may be mixed with the fertilizer and applied at 14–29 kg Cu/ha (12.5–26 lb/acre) on newly cultivated muck. Subsequent applications may be made every 2 or 3 years at about one-third the rate recommended for new muck.

MANGANESE

Manganese deficiency shows up as a yellowing between leaf veins. Foliar applications of manganese sulfate are recommended, starting when the plants are about 15 cm tall with 1.5–2.75 kg manganese sulfate/ha in 300 L water, repeated in 4–5 sprays, 10 days apart. Use the low rate on small plants, increasing the rate as the season prgresses. Soil application is not recommended.

See the section *Manganese*, on page 19, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

MOLYBDENUM

Molybdenum deficiency may occur when onions are grown on moderately acid to strongly acid muck soils. A seed treatment has proven beneficial. The treatment is accomplished by dissolving 15 g of sodium molybdate in 45 mL of water. Spray this solution from an atomizer bottle on 2.3 kg seed (5 lb) spread thinly on a plastic sheet. Do not use excessive water, as this can cause the chemical to penetrate the seed embryo and cause injury. Mix seed thoroughly and let dry. For foliar application rates, see Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

ZINC

Zinc-deficient plants develop yellow-striped foliage. They become stunted, twisted and bent. Deficiencies occur mainly with shallow muck soils or where calcareous subsoils are mixed with the muck. See the section *Zinc*, on page 20, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information see the section *Plant Analysis*, on page 3.

Table 9–57. Sweet Onion Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts Per Million (ppm)				
Most recently mature leaf	just prior to bulb initiation	2–3	0.2–0.5	1.5–3	0.6–0.8	0.15–0.3	0.2–0.6	–	10–20	15–20	10–25	5–10

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*, 5th Edition. John Wiley & Sons, Inc. New York.

Table 9–58. Onion Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl-M	20 mL per 100 kg seed	damping-off	For use in commercial seed-treatment plants only.
Thiram 75 WP	thiram	65–80 g per 25 kg seed	damping-off	
Pro-Gro	carbathiin-thiram	25 g per 1 kg seed	smut	Pro-gro treated seed may be stored for up to 4 months.
Governor 75 WP	cyromazine	66.7 g per 1 kg seed	onion maggot	Imported seed only. Only on muck soils. Do not plant treated seed in the same field in consecutive years.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–57, *Sweet Onion Nutrient Sufficiency Ranges*, on page 134.

Integrated Pest Management

See OMAFRA Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*, for a comprehensive guide to IPM for onions.

Diseases

DAMPING-OFF AND ROOT ROTS

For more information, see Chapter 8, on page 59, and Table 9–58, *Onion Seed Treatments*, above.

To manage damping-off and root rots in greenhouse transplants, see Table 9–59, *Allium Disease Control Recommendations*, on page 136.

BOTRYTIS LEAF BLIGHT

Identification: White, oval-shaped spots with silvery halos develop on infected leaves. Lesions are 1–5 mm long. Severely infected leaf tips die back. Infection is more likely to occur if the leaves are injured, bruised or starting to die-back.

Period of Activity: Botrytis leaf blight typically develops after mid-June when temperatures and leaf-wetness periods are sufficient for infection to occur. Optimum conditions for infection are 12 hr of leaf wetness at 15°C–18°C (59°F). Levels of infection are reduced at temperatures above 27°C (81°F).

Thresholds: A forecasting model called BOTCAST has been developed to help predict botrytis leaf blight outbreaks. If BOTCAST is not available, use a threshold of 1 active lesion/leaf on dry bulb and Spanish onions. For green bunching onions, the threshold is 0.5 active lesions/leaf. After the first spray is applied, subsequent sprays should be applied 8 days later if the probability of rain is greater than 30%.

DOWNY MILDEW

Identification: Infections usually occur in patches within the field. A violet or greyish growth develops, and the tissue dies quickly, resulting in straw-coloured lesions and eventual plant death.

Period of Activity: This disease is more common in cool, wet seasons. Infection occurs when the foliage remains wet for 2–6 hr at 3°C–14°C (37°F–57°F). The incubation period lasts for 10–16 days. A relative humidity of 95% or greater will also promote further infections.

Thresholds: A forecasting model called DOWNCAST has been developed to help predict downy mildew outbreaks. If DOWNCAST is not available, apply protective fungicides during cool and humid weather conditions.

Botrytis, Downy Mildew and Purple Blotch Management Notes

All three of these diseases overwinter in crop debris. Dormant *Botrytis* sclerotia can remain viable for many years. Practice a 2–3-year crop rotation and remove cull onions from the field. See Table 9–59, *Allium Disease Control Recommendations*, on page 136.

PURPLE BLOTCH

Identification: The 1–3 cm (0.5–1 in.) spots are brown with reddish-purple margins. There may be a yellow zone around the lesions. Infected leaves may be weakened and easily blown over.

Period of Activity: Infection occurs when warm weather, 18°C–30°C (64°F–86°F), coincides with prolonged dews or leaf wetness. Weaker plants or those affected by other diseases are at highest risk.

Thresholds: None established.

Table 9–59.
Allium Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
GREENHOUSE TRANSPLANT DISEASE CONTROL (DAMPING-OFF AND ROOT ROTS)						
dithiocarbamate (group M2)	oxine benzoate	No-Damp		10 mL/L of water		**Damping off.** Soil treatment.
SMUT						
dithiocarbamate (group M3)	mancozeb	Dithane DG	4.4–8.8 kg	1.76–3.5 kg	100	Apply in-furrow at seeding time. Use high rate only where smut pressure is high.
DOWNY MILDEW, BOTRYTIS LEAF BLIGHT, PURPLE BLOTCH						
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.4–4.8 L	0.96–1.92 L	7	Dry bulb. **Botrytis leaf blight only.** Maximum 3 applications/yr.
					14	Green bunching. **Botrytis leaf blight only.** Maximum 5 applications/yr.
dithiocarbamate (group M3)	mancozeb	Dithane DG	2.25–3.25 kg	0.9–1.3 kg	10	**Labelled for dry onions only.**
		Manzate DPro-Stick	2.25–3.25 kg	0.9–1.3 kg	10	
		Penncozeb 80 WP	2.25–3.25 kg	0.9–1.3 kg	10	
	zineb	Zineb 80 W	0.85–3.3 kg	0.34–1.32 kg	7	**Onions only.**
phenylamide + dithiocarbamate (group 4 + M3)	metalaxyl-M + mancozeb	Ridomil Gold MZ 68 WP	2.5 kg	1 kg	7	**Onions only.** For downy mildew only. Apply before first outbreak of disease. Maximum 3 applications/yr.
QoI + carboxamide (group 11 + 7)	pyraclostrobin + boscalid	Pristine WG	1.0–1.3 kg	400–520 g	7	Use high rate for suppresion of downy mildew. Maximum 6 applications/yr. Do not make sequential applications. 3-day re-entry interval.
carboxamide (group 7)	boscalid	Lance WDG	475 g	190 g	7	**For purple blotch and botrytis leaf blight.** Maximum 6 applications/yr. Apply before disease develops. Do not apply more than 2 sprays before rotating to a different fungicide family. 4-hr re-entry.
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	224–336 g	7	**For purple blotch and downy mildew only.** Maximum 3 applications/yr. Do not apply more than 2 sprays before rotating to a different fungicide family. 72-hr re-entry interval for hand-thinning activities.
dicarboximide (group 2)	iprodione	Rovral[2]	0.75–1.5 kg in 300–500 L water	0.3–0.6 kg in 30–50 gal water	15	**Onions and leeks only.** Maximum 4 applications/yr. 12-hr re-entry.
phosphonate (group 33)	fosetyl-al	Aliette WDG	2.8 kg	1.12 kg	7	**Onions only.** For downy mildew and purple blotch. Maximum 5 applications/yr. 12-hr re-entry.
phenylpyrroles + anilino-pyramidines (group 12 + 9)	cyprodinil + fludioxonil	Switch 62.5 WG	775–975 g	310–390 g	7	**Dry bulb and green onions only.** For botrytis leaf blight and supression of purple blotch. Maximum 3 applications/yr. Do not make more than 2 sequential applications.
biological	*Bacillus subtilis*	Serenade Max	3–4.5 kg	1.2–1.8 kg	0	**Botrytis.** Begin applications at the first sign of disease or when conditions favour disease development.
			3–6 kg	1.2–2.4 kg	0	**Downy mildew.** Begin applications at the first sign of disease or when conditions favour disease development.

[1] PHI = Pre-Harvest Interval.

[2] Rovral when tank-mixed with label rates of maneb or mancozeb will control botrytis leaf blight and downy mildew. Apply on a preventative basis. This tank-mix combination will help reduce the chance of resistance to Rovral.

ONION SMUT

Identification: Most muck soils are infested with onion smut spores. When untreated, resulting losses may be as high as 50%–80%. Infected plants appear thickened, darker and slightly twisted. Cut leaves expose a mass of black teliospores on the inside. Most plants die within 3–4 weeks of infection.

Period of Activity: The smut spores are long-lived and may last up to 20 years in the soil. Infection occurs at 10°C–12°C (50°F–54°F) within 2–3 weeks of seeding.

Thresholds: None established.

Management Notes: The only practical means of controlling onion smut is the use of a seed treatment or fungicide in the seed furrow. See Table 9–58, *Onion Seed Treatments*, on page 135, and/or Table 9–59, *Allium Disease Control Recommendations*, on page 136.

BOTRYTIS NECK ROT AND SMUDGE

Identification: Botrytis-infected bulb tissue becomes greyish. Mould may also develop. Black sclerotia eventually appear in the affected tissue. The smudge fungi form black concentric rings near the neck and on the outer scales of the bulb.

Period of Activity: Both botrytis neck rot and smudge are most commonly found on bulbs after harvest, but they can appear on maturing bulbs in the field. The fungi of both diseases can survive in the soil for several years. Smudge prefers warm, wet weather. Botrytis infections occur during cool, wet conditions.

Management Notes: Follow a 2–3-year crop rotation and remove cull onions from the field. Proper curing and drying reduces disease development in storage. Artificial heat curing may reduce problems in humid areas of the province. Onions with thick necks, nicks or bruises should be graded-out prior to storage. Most commercial onion cultivars are susceptible to neck rot, particularly Spanish and white types. Yellow and red-skinned onions are resistant to smudge.

ALLIUM WHITE ROT

Identification: Foliar symptoms include yellowing, wilting and stunted plants. White fungal growth with small pinhead-sized sclerotia may be visible at the base of the plant. The fungus causes a watery rot and disintegration of infected bulbs. This disease is not always present at harvest but may show up in storage.

Period of Activity: The sclerotia and mycelium overwinter in soil and plant debris. Soil infested with allium white rot is spread by machinery, animals, pallet boxes, wind and water. Warm soil temperatures, greater than 24°C (75°F) are less conducive to allium white rot.

Management Notes: Allium white rot can survive in the soil for many years. Remove cull onions from field areas and wash all implements used in infested fields. Field flooding followed by crop rotation has been shown to reduce allium white rot in muck soils. Recent research indicates that sclerotial germination stimulants (such as garlic oil, dailly disulphides, etc.) can significantly reduce white rot.

PINK ROOT

Identification: This disease is present in many areas. It will not affect the yields of healthy crops, grown on quality soils. Infected roots have a pinkish-red colour and eventually turn purplish-black. The root system may be substantially reduced, causing the plant to turn yellow, wither and become stunted.

Period of Activity: The fungus can survive in the soil for several years in the absence of host plants. It mainly attacks the roots when soil temperatures rise to 26°C (80°F).

Management Notes: Problem fields will require a rotation of several years out of allium crops.

FUSARIUM BASAL ROT

Identification: Early symptoms include the yellowing of leaves and tip dieback. As the disease progresses, the whole plant may collapse. The basal plate of the onion becomes pinkish-brown. Secondary bacterial rots may also develop. If the infection occurs late in the season, the symptoms may not show up until the onions are in storage.

Period of Activity: Basal rot occurs under warm soil temperatures. A temperature of 29°C (84°F) is optimum for disease development. Basal rot is not prevalent every year in all areas. It is often observed on Spanish onions growing in southwestern Ontario.

Management Notes: Follow a long crop rotation and use disease-free transplants.

LEEK RUST

Identification: This is an occasional disease of leeks. Rust-coloured spores develop on the upper and lower leaf surfaces. Disease is enhanced on stressed plants.

Period of Activity: Rust occurs during high humidity and low rainfall conditions.

Management Notes: Follow a 2–3-year crop rotation and use only certified seed. Plant into well-drained soils. Keep onion and leek crops well separated.

Bacterial Diseases

SOFT ROT, SLIPPERY SKIN AND SOUR SKIN

Identification: These diseases are characterized by a watery rot and strong smell. Onions with slippery skin may appear sound on the surface. However, the inner rotted portions will slide out through the neck when squeezed. Sour skin first appears as tan or brown rotted leaves followed by a soft rot near the neck.

Period of Activity: Infections begin during wet field conditions. Tissues damaged by onion maggot or other diseases are most prone to infection.

Management Notes: Minimize all types of injury to bulbs (sunscald, bruising and mechanical damage) and provide good storage conditions. Do not put diseased or damaged onions into storage. Avoid using overhead irrigation when the crop is approaching maturity, especially with Spanish types. Harvest onions only when fully mature.

For more information on onion diseases, see the OMAFRA Factsheet, *Identification of Diseases and Disorders of Onions,* Order No. 95-063.

IRIS YELLOW SPOT VIRUS

This is a new disease in Ontario. Iris yellow spot virus (IYSV) was first detected in Ontario during the 2007 growing season. IYSV is a persistant tospovirus that is vectored by onion thrips. Onion thrips larvae pick up the virus from infected plants and transmit the virus for the remainder of their lifespan. Research in the U.S. has shown that disease incidence is highest at field edges and that the presence of IYSV in a field can result in a reduction in bulb size.

Virus symptoms include bleached or straw-coloured diamond-shaped lesions. Some active lesions have a yellow halo surrounding a green island of leaf tissue. Lesions often appear on the inner leaf tissues of the bottom leaves where the majority of thrips feeding occurs. For more information, see *Onion Thrips*, right, and Table 9–60, *Allium Insect Control Recommendations*, on page 139.

Insects

CUTWORMS, WIREWORMS

For identification and management information on these common vegetable insects affecting onions, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–60, *Allium Insect Control Recommendations*, on page 139.

ONION THRIPS

Identification: Usually under 2 mm in length, adult thrips have straw-brown bodies and four wings fringed with hairs. Nymphs are smaller, wingless and pale white in colour. Thrips feeding damage appears as longitudinal, silvery rasping on leaf surfaces. Severe injury may cause reduced yields and increase susceptibility to diseases.

Period of Activity: Thrips favour hot, dry weather conditions. There are usually several generations per year.

Thresholds: The threshold for dry cooking onions, leeks and Spanish onions is 1 thrips per leaf.

Management Notes: Early detection of thrips is key to successful control. Research in Ontario has shown that high water volumes help to ensure the insecticide penetrates into the leaf axils where the majority of onion thrips are found. Also, spray applications made in the evening have provided better control than applications made during the day. See Table 9–60, *Allium Insect Control Recommendations*, on page 139.

Natural controls include a host of predators (such as minute pirate bugs) and some parasites. Heavy rainfall is effective in knocking thrips off the plant for a short time.

ONION MAGGOT

Identification: The onion maggot fly lays eggs around the base of onion plants. Larvae tunnel into the basal plate of the onion, causing the plant to wilt and die. Small onion plants are most susceptible to feeding injury. Crop losses of 50%–70% may occur if in-furrow control measures are not used.

Period of Activity: The onion maggot overwinters as a pupa in the top 15 cm of the soil. The three generations found in Ontario emerge in early June, July and late August. This pest is present in all onion fields in the Bradford, Keswick and Thedford-Grand Bend areas.

Thresholds: First-generation onion maggot thresholds are a combination of trapping and visual scouting. Place four traps (of 3 sticky boards each) centrally along each

Table 9–60.
Allium Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
ONION MAGGOT						
Soil treatment (in-furrow granular)[2]						
organophosphate (group 1B)	chlorpyrifos[3]	Lorsban 15 G	8–16 kg	3.2–6.4 kg	109	**Dry onions only.** 24-hr re-entry.
					97	**Pickling onions only.** 24-hr re-entry.
		Pyrifos 15 G	8–16 kg	3.2–6.4 kg	109	**Dry onions only.** 24-hr re-entry.
					97	**Pickling onions only.** 24-hr re-entry.
Foliar sprays for onion maggot flies						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	175 mL	70 mL	3	**Onions only.**
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.44 kg	10	**Onions only.**
		Diazinon 500 E	1.1 L	0.44 L	10	
	naled	Dibrom	550 mL	220 mL	4	**Onions only.**
THRIPS						
pyrethroid[3] (group 3)	cyhalothrin-lambda	Matador 120 EC	188 mL in 500 L water	75.2 mL in 50 gal water	14	Maximum 3 applications/yr. 24-hr re-entry.
	cypermethrin	Ripcord 400 EC	175 mL	70 mL	3	**Onions only.** Maximum 3 applications/yr.
	deltamethrin	Decis 5 EC	200 mL	80 mL	5	Maximum 1 application/yr.
organophosphate (group 1B)	naled	Dibrom	550 mL	220 mL	4	
CUTWORMS						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	175 mL	70 mL	21	Do not disturb soil for 5 days after treating.
	permethrin	Pounce	180–390 mL	72–156 mL		Apply up to the 5-leaf stage. Do not disturb soil for 5 days after treating. Use high rate on muck soils.
organophosphate (group 1B)	chlopyrifos	Lorsban 4E	2.4–4.8 L	0.96–1.92 L	60	**Dry onions only.** Apply between 2–5-leaf stage. 24-hr re-entry.
		Pyrinex 480 EC	2.4–4.8 L	0.96–1.92 L	60	

[1] PHI = Pre-Harvest Interval.

[2] Refer to the label for spacing and planter specifications.

[3] Resistance to these insecticides has been observed in Ontario muck soils.

field edge. Check traps weekly. Assess the percent damage using plots containing 100 onions repeated four times within the field:

Amount of damage		Trap Counts	Action
< 2% damage			Do not spray.
2–5% damage	and	5 flies/trap/day	Spray.
> 5% damage	and	2 flies/trap/day	Spray.

Management Notes: Apply a granular insecticide at seeding or use treated seed. If these treatments work, first-generation damage may be negligible. Seedlings killed by the first generation are often compensated for with more rapid growth in adjacent onions.

Treatments against adult flies of the first and second generation are not recommended on dry, cooking or Spanish onions. Research in Ontario, New York and Michigan has confirmed that spraying for adult flies does nothing to prevent or reverse onion maggot damage.

LEEK MOTH

In Eastern Ontario and Quebec, leek moth damage has been recorded in garlic, leek and onion fields. The larvae tunnel mines and create pinholes in the leaf tissue and scapes, sometimes causing distortion. They occasionally attack the bulb and stem. For further information, see the section *Leek Moth*, on page 121, or visit www.ontario.ca/crops.

For more information on insect management for onions, see the following OMAFRA Factsheets and publication:

- *Thrips on Onions and Cabbage,* Order No. 99-027
- *Onion Maggot Control,* Order No. 00-017
- Publication 700, *IPM for Onions, Carrots, Celery and Lettuce in Ontario*

Nematode Control

See the section *Nematodes*, on page 63, for nematode control recommendations. For more information, see the OMAFRA Factsheet *Bulb and Stem Nematode in Onions and Carrots*, Order No. 00-043.

Physiological Disorders

Ozone Injury

This injury begins as small flecks, which can form into whitish spots. These spots can be confused with *Botrytis;* however, they do not have a distinct halo.

Sprout Inhibitor Injury

Maleic hydrazide applied to immature crops can result in spongy bulbs. See the section *Harvest and Storage*, below, for more details.

Sunscald

Sunscald causes severe damage to onions curing in the field. Turn onions during curing to avoid injury. Sunscald injury leads to secondary bacterial infections, which can result in severe storage losses.

Harvest and Storage

Dry Bulb Onions (cooking, Spanish and shallots)

Weather and soil conditions often determine the timing of harvest and quality of dry bulb onions. Signs of maturity are soft neck tissues, fallen-over tops and dead roots. Mature onions have better longevity in storage.

The proper use of maleic hydrazide (Royal MH 60) inhibits sprouting and lengthens the storage life of many onion cultivars. Cultivars with a naturally short storage life do not benefit from maleic hyrazide applications.

The optimum time for spraying is when 50% of the tops have fallen, but tops are still green. This usually occurs 8–14 days before harvest. Plants with less than three green leaves and/or severely diseased foliage will not absorb maleic hydrazide.

Onions are typically cured in the field. Optimum curing occurs in average air temperatures of 24°C–30°C (75°F–86°F) and a relative humidity is at least 60%. In humid areas, or during cool, wet harvest periods, artificial curing can be beneficial. Place pallet boxes into well-ventilated storage facilities and heat to 35°C (95°F) and 60% relative humidity for 3–4 days.

Storage conditions must be maintained at 0°C (32°F) and 65%–70% relative humidity with good air circulation. Properly stored cooking onions and shallots can be held for 8 months. Spanish onions may last for 2 months in storage.

Bunching (Green) Onions and Leeks

Green bunching onions and leeks are harvested as a whole plant. The roots are trimmed off close to the base of the bulbs and the older, outer scales are removed.

Green bunching onions may be stored for 3–4 weeks, whereas leeks can be stored for 3–6 months. Consistent post-harvest chilling near 0°C (32°F) and careful post-harvest handling will maximize their storage life.

For more information, see the following OMAFRA Factsheets and publication:

- *Leek Production,* Order No. 91-004
- *Shallots: What They Are and How to Grow Them,* Order No. 98-037
- Publication 487, *Onions*

PARSNIPS

Production Requirements

Parsnips require deep, loose, fertile, sandy loam soils with a preferred pH of 6.5. Well-drained muck soils with a target pH of 5.5 are also suitable. Parsnips take 100–130 days to mature and should be planted as soon as soil conditions permit in the spring.

In Ontario, some parsnips are lifted in late August and sold fresh. Most of the crop is harvested in October and November for winter storage. A portion of the crop may be left in the ground over the winter and harvested in early spring the following year.

Average Yield

Crop	per acre	per hectare
Parsnips	400–500 bushels of graded product	1,000–1,250 bushels of graded product

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Planting, Seeding and Spacing

The minimum temperature for seed germination is 2°C (35°F). Optimum planting conditions occur when soil temperatures reach 10°C–21°C (50°F–70°F). Planting into cool soil conditions may result in reduced stands due to poor germination, low vigour and increased seed decay.

Poor stands also occur if an over-worked soil surface becomes baked or crusted before the seedlings emerge. For more information on how to improve soil structure and prevent crusting, see Chapter 2, *Soil Management*, on page 21.

Always use seed produced the preceding year.

	Metric	Imperial
Rate:	3–5.5 kg/ha	3–5 lb/acre
Row spacing:	45–75 cm	18–30 in.
In-row spacing:	3–6 cm	1–2.5 in.
Depth: (always plant into moisture)	6–20 mm	<1 in.

Fertility

Fertilizer requirements are the same as for carrots. (See Table 9–61, *Parsnip Nitrogen Recommendations*, above.)

Table 9–61.
Parsnip Nitrogen Recommendations

Soil Type	Actual N	
	kg/ha	lb/acre
Mineral Soils		
Preplant	70	62
Side-dress	40	36
Total	**110**	**98**
Muck Soils		
Preplant	60	53

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, parsnips grown on both mineral and muck soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, parsnips grown on both mineral and muck soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59.

PHOMA CANKER AND LEAF SPOT, ITERSONILIA CANKER

Identification: Both diseases cause brown cankers on the crown and root shoulders. Leaf symptoms include small (1-mm) spots with yellow-green halos. Phoma cankers are often embedded with small, black, spores.

Table 9–62.
Parsnip Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]
PHOMA CANKER					
chloronitrile (group M5)	chlorothalonil	Bravo 500	2.8 L	1.12 L	7
CARROT RUST FLY (ADULTS ONLY)					
organophosphate (group 1B)	diazinon	Diazinon 500 E	1.1 L	0.44 L	10
		Diazinon 50 W	1.1 kg	0.44 kg	10

[1] PHI = Pre-Harvest Interval

Period of Activity: Phoma canker and leaf spot appear in mid-August. Development is favoured by moderate temperatures, rain and high humidity.

Itersonilia canker requires cool, wet conditions (temperatures around 20°C or 68°F). The fungus overwinters in infected roots and is spread within the field by spores. Itersonilia can also spread through infested seed.

Thresholds: None established.

Management Notes: Phoma canker development may be reduced by harvesting before maximum root and shoulder development. High ridging to cover the shoulder of the roots throughout the season may minimize itersonilia canker infections. Control of carrot rust fly will help reduce secondary itersonilia infections. Follow a long rotation and bury infected residue. See Table 9–62, *Parsnip Disease and Insect Control Recommendations*, above.

Insects

CARROT RUST FLY

See the section *Carrot Rust Fly*, on page 98. If monitoring indicates a need, apply as directed in Table 9–62, *Parsnip Disease and Insect Control Recommendations*, above.

Root-Knot Nematode Control

See the section *Nematodes*, on page 63.

Harvest and Storage

Roots may be kept in cold storage for 4–6 months at 0°C (32°F) and 98%–100% relative humidity. The sweet, nut-like flavour of parsnips develops after the roots have been exposed to temperatures near freezing (late September and October). Mature roots that have not been exposed to low field temperatures may be stored for 2 weeks at 0°C–1°C (32°F–34°F) to develop flavour. Extremely low temperatures in storage may damage root tissues. Parsnips will freeze at –1.7°C (29°F).

Caution

Some individuals may be sensitive to furocoumarins, the natural chemicals found in parsnip foliage. The level of these substances increases if parsnips are diseased. Using rubber gloves when handling parsnip foliage and leg protection when walking in the field will prevent the development of skin rashes.

PEAS

Production Requirements

Peas are a hardy, cool-season vegetable crop. Optimum pea growth occurs at temperatures in the range of 10°C–17°C (50°F–63°F). Crops grown during the warmer part of the summer (temperatures above 24°C or 75°F) will develop overly fibrous pods and starchy seeds. Most pea varieties mature in 50–60 days.

Peas are suited to well-drained soils. Avoid planting the early crop into heavy soils or variable fields, as they are more prone to root rots and seed insects. The target soil pH is 6.1–6.5. Consider innoculating the seed with rhizobia if peas have not been grown in a field in the past 5 years.

Average Yields

Type	per acre	per hectare
Processing	2–3 tons	4–7 tonnes
Fresh market	150 bu	375 bu

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under Ontario growing conditions. A list of seed suppliers is available in Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding and Spacing

Seed size varies considerably between varieties. Adjust the planting rate according to both seed size and percent germination. Pea seed requires a minimum soil temperature of 4°C (39°F) for germination. Planting into colder soils will slow early growth, resulting in uneven stand establishment. Optimum germination occurs at temperatures of 4°C–24°C (40°F–75°F.)

	Metric	Imperial
Row Spacing:	15–20 cm	6–8 in.
In-Row Spacing:	4–5 cm	1½-2 in.
Rate:	100–300 kg/ha	90–270 lb/acre
Depth: (Always plant into moisture.)	2.5–5 cm	1–2 in.

Fertility

Nitrogen

Where phosphate and potash are required, apply 15 kg N/ha (13 lb N/acre) at seeding. If no phosphate and potash are required, the nitrogen may be omitted.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 16 mg P per L soil (ppm) or higher, peas are unlikely to respond to additional phosphate applications. For soils testing lower than 16 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 121 mg K per L soil (ppm) or higher, peas are unlikely to respond to additional potash applications. For soils testing lower than 121 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, apply and incorporate them prior to planting. Do not drill fertilizer with the seed.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

These diseases are the most prevalent causes of yield loss in peas. For information on identification and management, see the section *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)*, on page 59.

Also see Table 9–63, *Pea Seed Treatments*, on page 144.

ASCOCHYTA (MYCOSPHAERELLA) BLIGHT

Identification: Infected seedlings develop symptoms similar to damping-off. The stem tissue above the soil-line turns black, reducing water and nutrient uptake. Plants become stunted and weakened.

Infections on established plants cause brown spots on the leaves and stems. The spots have a distinctive dark border. Infected leaves eventually turn yellow and dry off. Plants remain standing and become straw-like.

Development: This disease complex is transmitted through seed-, soil- and wind-borne spores. Spores travel for long distances and can infect large areas. Humid conditions in the crop canopy promote disease development.

Management Notes: Follow a 4–5-year rotation away from peas and other legume crops. Promote vigorous early-season growth by planting into warm soils and

Table 9–63.
Pea Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Insecticide and Fungicide Combination				
Agrox B-2	diazinon + captan	80 g/ 25 kg seed	seed and root maggots, seed decay, damping-off	Use seed within 1 month of treatment. Do not use on seed previously treated with an insecticide.
Agrox CD	diazinon + captan	50 g/ 25 kg seed	seed corn maggot, seed decay, damping-off	Use on seed previously treated with captan or thiram. Do not use on seed previously treated with an insecticide
Fungicide only				
Vitaflo 280	carbathiin + thiram	260–330 mL/ 100 kg seed	seed decay, damping off caused by *Pythium*, *Rhizoctonia* and *Ascochyta*	For use in commercial seed treatment applicators. Do not store treated seed. Do not feed crop to livestock for 4 weeks after planting.
Apron MAXX RTA	fludioxonil + metalaxyl-M	325 mL/ 100 kg seed	seedling blight and damping-off caused by *Fusarium*, *Pythium* and *Rhizoctonia*. Seed-borne ascochyta blight.	Ensure uniform coverage. 30-day re-plant interval for all non-registered crops.
Apron XL LS	metalaxyl-M	20–40 mL/ 100 kg seed	pythium damping-off and root rot	For use in commercial seed-treatment applicators.
Apron FL	metalaxyl	32–110 mL/ 100 kg seed	pythium seed decay and damping-off	For use in commercial seed-treatment plants only. Do not feed crop to livestock for 4 weeks after planting.
Allegiance FL	metalaxyl	32–110 mL/ 100 kg seed	pythium seed decay and damping-off	For use in commercial seed-treatment plants only. Do not feed crop to livestock for 4 weeks after planting.
Captan FL	captan	70 mL/ 25 kg seed	seed decay, damping-off, root rot	
Thiram 75 WP	thiram	25–35 g/ 25 kg seed	seed decay, damping-off	Do not feed treated clippings to livestock.
Insecticide Only				
Cruiser 5 FS	thiamethoxam	50–83 mL/ 100 kg seed	potato leafhopper, seedcorn maggot and wireworm	**For use on imported seed only.** Not for domestic commercial or on-farm seed treatment. Use high rate for wireworm. Use high rate where populations are expected to be high.

minimizing compaction. See Table 9–64, *Pea Insect and Disease Control Recommendations*, on page 145.

WHITE MOULD (SCLEROTINIA)

White mould is an occasional problem in processing peas. Infection occurs as a result of warm, wet conditions during flowering. A white, cottony growth develops on the pods. Hard, black sclerotia are often imbedded in the fungi. These sclerotia may be difficult to grade-out during processing.

White mould is commonly a problem in beans (snap, edible and soy). Follow a 2-year rotation away from all white mould host crops. For more information, see the section *White Mould (Sclerotinia)*, on page 74, and Table 9–64, *Pea Insect and Disease Control Recommendations*, on page 145.

POWDERY MILDEW AND DOWNY MILDEW

Powdery mildew and downy mildew are also an occasional problem in peas. These diseases overwinter in the southern U.S. and are blown into Ontario annually. As a result, infections generally occur at the tail-end of the harvest season.

Powdery mildew infections may reduce the yield and quality of late crop peas. Downy mildew infections occur during cool, wet seasons. A dense grey mould develops on the underside of the leaf. Severe infections will cause the plants to turn slimy and fall over.

Insects

SEEDCORN MAGGOTS, WIREWORMS, APHIDS, CUTWORMS

For identification and management information on these common vegetable insects affecting peas, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. Also see Table 9–63, *Pea Seed Treatments*, above, and Table 9–64, *Pea Insect and Disease Control Recommendations*, on page 145.

Table 9–64.
Pea Insect and Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
MYCOSPHAERELLA AND ASCOCHYTA BLIGHT						
QoI (group 11)	pyraclostrobin	Headline EC	400–600 mL	160–240 mL	7	48-hr re-entry
carboxamide (group 7)	boscalid	Lance WDG	420 g	168 g	7	Maximum 2 applications/yr. 4-hr re-entry.
WHITE MOULD (SCLEROTINIA)						
carboxamide (group 7)	boscalid	Lance WDG	560–770 g	224–308 g	7	Maximum 2 applications/yr. 4-hr re-entry.
APHIDS						
pyrethroid (group 3)	lambda cyhalothrin	Matador 120 EC	83 mL in 200 L water	33 mL in 18 gal water	14	May also control lygus bugs. Maximum 3 applications/yr. Do not feed or graze treated vines. 24-hr re-entry.
carbamate (group 1A)	pirimicarb	Pirimor 50 DF	150–275 g	60–110 g	6	
	methomyl	Lannate TNG	510 g	204 g	1	24-hr re-entry.
organophosphate (group 1B)	dimethoate	Cygon 480	275–425 mL	110–170 mL	3	Do not feed or graze vines within 21 days of last application. Maximum 2 applications/yr.
		Lagon 480	275–425 mL	110–170 mL	3	
	malathion	Malathion 25 W	4.25 kg	1.7 kg	3	
		Malathion 500 E	2.25 L	0.9 L	3	
	naled	Dibrom	1.1–2.2 L	0.44–0.88 L	4	**Processing only.**
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4EC	1.5–2.0 L	0.6–0.8 L	7	**Processing only.** Do not feed or graze treated vines. Maximum 2 applications/yr.
		Thionex 50 WP	1.1–1.75 kg	0.4–0.7 kg	7	
SLUGS						
inorganic	ferric phosphate	Sluggo	25–50 kg	10–20 kg	0	Use higher rates on severe infestations.
CUTWORMS						
pyrethroid (group 3)	lambda cyhalothrin	Matador 120 EC	83 mL in 200 L water	33 mL in 18 gal water	14	Apply in the late evening or at night. Do not feed or graze treated vines. 24-hr re-entry.
	permethrin	Pounce 384 EC	180–390 mL	72–156 mL		Apply in the late evening or at night. Apply up to 5-leaf stage. Use high rates on dry soils and/or large cutworms. Do not disturb soil for 5 days after treating.

[1] PHI = Pre-Harvest Interval.

Harvest and Storage

Remove the field heat from peas immediately after harvest. Store at 0°C (32°F) and 95%–98% relative humidity. Under ideal conditions, fresh-market peas will store for 1–2 weeks.

Early harvested peas are an ideal opportunity to include a cover crop in your rotation. Not only do cover crops protect the soil from wind and water erosion, they also scavenge residual nitrogen from the soil and add organic matter back into the soil. For more information on cover crops, see Chapter 2, *Soil Management*, on page 21.

PEPPERS

Production Requirements

Peppers grow well in a wide variety of well-drained mineral soils. Lighter soils produce earlier crops. Peppers perform best at a pH of 6.0–6.8. Cultivars grown in Ontario take from 60–76 days to progress from transplanting to mature green fruit. Full-size green fruit are ready to harvest approximately 30–40 days after pollination. Add 20–25 days for ripe colour to develop.

Average Yields

Type	per acre	per hectare
Processing	10–12 tons	22–27 tonnes
Fresh market	6–8 tons	13–18 tonnes

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. Processors will determine variety selection for crops produced under a processing contract. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding and Spacing

Plant 200 g of seed to get enough transplants for 1 ha (3 oz/acre). For more information, see the section *Transplanting*, on page 39.

	Row Spacing	In-Row Spacing	Bed Centres
Single rows:			
Early varieties	1.0 m (3 ft)	30 cm (12 in.)	
Standard varieties	1.0 m (3 ft)	45 cm (18 in.)	
Twin rows:	45 cm (18 in.)	45 cm (18 in.)	1.5 m (5 ft)

Plasticulture

Peppers respond well to plastic mulch, row covers and drip irrigation. However, keep in mind that peppers are very sensitive to low temperatures. Row covers may not provide significant frost protection. Monitor the temperature inside the row cover regularly and ventilate when it reaches 35°C (95°F) or higher. Remove the cover once conditions are favourable for good growth and prior to pollination. To control weed growth under the mulch, choose one that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch. For more information, see the section *Season Extension*, on page 34.

Table 9–65. Pepper Nitrogen Application Schedule

Method	Actual N	
	per hectare	per acre
Soil-applied		
Preplant	35 kg	31 lb
Side-dressed	35 kg	31 lb
Total	**70 kg**	**62 lb**
Fertigated		
Preplant (broadcast)	35 kg	31 lb
Transplanting to fruit set	3–5 kg/week	2.7–4.5 lb/week
Fruit sizing	7–10 kg/week	6–9 lb/week
Harvest	3–5 kg/week	2.7–4.5 lb/week

Fertility

Nitrogen

Reduce the nitrogen (N) application if manure is applied or legume sod is plowed down. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Broadcast and incorporate the recommended preplant nitrogen, along with the required phosphate and potash, prior to planting. Side-dress the remainder of the nitrogen after first fruit set.

For fertigated peppers, broadcast and incorporate the recommended preplant nitrogen, along with all the required phosphate and half the required potash. Apply equal rates of nitrogen and potash through the drip tape according to the schedule in Table 9–65, *Pepper Nitrogen Application Schedule*, above. For more information, see the section *Fertigation*, on page 30.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, peppers are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

STARTER SOLUTION

At transplanting, apply a high-phosphorus starter solution. Starter fertilizer is especially important when planting in cool soils. Starter fertilizers are available in several

Table 9–66. Transplant Starter Solution Recommendations

Soil Temperature	Starter Concentration[1]
<18°C (64°F)	Use full label rate as recommended.
18°C–27°C (64°F–81°F)	Use half of recommended rate.
>27°C (81°F)	Starter not normally required.

[1] Under high temperature or dry conditions or in sandy soils with less than 2% organic matter, use half the recommended rates.

forms, including liquids (10-34-0 or 6-24-6), soluble or granular materials (10-30-20 or 10-52-10). Apply according to the recommendations in Table 9–66, *Transplant Starter Solution Recommendations*, above.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, peppers are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information, see the section *Plant Analysis*, on page 3.

Use sufficiency ranges as a reference and a guideline only. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–67, *Pepper Nutrient Sufficiency Ranges*, below.

Integrated Pest Management

TRANSPLANT PRODUCTION — DISEASE MANAGEMENT

Bacterial spot is a serious disease of peppers. Talk to your seed supplier to ensure that proper seed treatment prevention methods have been used. A greenhouse spray program with a fixed copper fungicide can greatly reduce the field infection rate later in the season. Apply every 5 days, starting 2½ weeks after seeding. Use low water volumes — wet the foliage, but not to excessive runoff. Ensure foliage is dry when shipping plants.

Fungicides registered for greenhouse transplant production are listed in Table 9–68, *Greenhouse Pepper Transplant Production Disease Control Recommendations*, on page 148. For more information on vegetable transplant production, see Chapter 5, *Seeding and Transplanting*, on page 37.

Diseases

DAMPING-OFF AND ROOT ROTS (TRANSPLANTS)

Sow seed in a sterilized soil-less mix. Seed treated with thiram is less susceptible to damping-off and root rots. Use 90 g of Thiram 75 WP per 25 kg of seed.

For more information on identification and management, see the section *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)*, on page 59.

ANTHRACNOSE, BOTRYTIS & ALTERNARIA

Anthracnose can infect immature or mature fruit. Disease development is greatest during warm, wet weather. Fruit lesions appear as small, sunken, water-soaked, circular spots. The lesions gradually expand and darken in the centre.

Botrytis and alternaria are not important pathogens of field pepper, and generally only infect fruit that have been wounded or damaged (i.e., by blossom-end rot or sunscald). Botrytis is more common in prolonged wet conditions. Botrytis occasionally attacks pepper seedlings.

Table 9–67. Pepper Nutrient Sufficiency Ranges

		N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
Plant Part	Time of Sampling	Percent (%)						Parts per Million (ppm)				
Most recently mature leaf	prior to blossoming	4–5	0.3–0.5	5–6	0.9–1.5	0.35–0.6	0.3–0.6	30–150	30–100	25–80	20–50	5–10
	first blossom opens	3–5	0.3–0.5	2.5–5	0.9–1.5	0.3–0.5	0.3–0.6					
	early fruit set	2.9–4	0.25–0.4	2.5–4	1–1.5	0.3–0.4	0.3–0.4					
	early harvest	2.5–3	0.2–0.4	2–3	1–1.5	0.3–0.4	0.3–0.4					

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*, 5th Edition. John Wiley & Sons, Inc. New York.

Table 9–68.
Greenhouse Pepper Transplant Production Disease Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	Notes
DAMPING-OFF, ROOT ROT					
pthalamide (group M3)	captan	Maestro 80 DF Supra Captan 80 WDG	1.25 kg/1,000 L of water. Apply 50–85 L of solution per 100 m² (1,076 ft²).		Soil drench treatment. 48-hr re-entry.
dithiocarbamate (group M2)	oxine benzoate	No-Damp	10 mL/L of water		Damping-off. Soil treatment.
BACTERIAL DISEASE					
inorganic (group M1)	copper hydroxide	Kocide 2000	3.2 kg	1.3 kg	Apply every 5 days, when warranted, to a maximum of 5 applications over a 4-week period prior to transplanting. Apply in low water volumes. 1 day pre-harvest interval. 24-hr re-entry.

POWDERY MILDEW

Powdery mildew of peppers can develop over a wide range of temperatures in low or high humidity conditions. A brownish, powdery growth is produced on the underside of the leaves. The upper leaf surface may develop yellow patches; in severe cases, the leaf turns completely yellow and drops off. Symptoms appear on older leaves first.

The pathogen has a wide host range, which includes tomato, however it has not been found to infect tomato in our growing region. Powdery mildew infecting tomato in the northeast U.S. and Ontario has been caused by a different organism; yet another organism causes powdery mildew of cucurbits.

BACTERIAL SPOT

Identification: Leaf lesions start as small, water-soaked spots that become large, irregular lesions with pale centres and dark edges. The centre of the spots may drop out, giving leaves a "shot-hole" or ragged appearance. If the disease is severe, leaves may turn yellow and drop. Fruit lesions start as green, circular, slightly raised spots, later becoming brown and scabby.

Development: Bacterial spot prefers temperatures of 24°C–30°C (75°F–86°F). Abundant rainfall and high humidity aid infection.

Thresholds: None established.

Management Notes: Use disease-free or disinfected seed. Do not plant diseased or unhealthy transplants. Avoid working in fields when foliage is wet. Overhead irrigation may spread this disease. If possible, time irrigation activities early in the day, allowing ample drying time for the foliage. Alternatively, install drip irrigation, which does not wet the foliage.

Some varieties have tolerance to bacterial spot races 1, 2 and 3. Copper fungicides may slow bacterial spot development; see the section *Bacterial Disease Control With Copper Fungicides*, on page 202, for copper use guidelines. See also Table 9–68, *Greenhouse Pepper Transplant Production Disease Control Recommendations*, on page 148, and Table 9–69, *Pepper Disease and Insect Control Recommendations*, on page 149.

See the OMAFRA Factsheet, *Bacterial Diseases of Tomato: Bacterial Spot, Bacterial Speck, Bacterial Canker*, Order No. 05-069.

VERTICILLIUM WILT

Identification: In peppers, verticillium wilt typically begins with wilting. If severe, leaf yellowing occurs, starting with the older leaves. Eventually, necrotic areas develop, starting at the leaf tips and edges, progressing to leaf drop. Split the plant stem at the base to check for discolouration of vascular tissue.

Development: Verticillium is a soil-borne disease. Symptoms are often more severe after fruit set or during dry periods. The presence of plant parasitic nematodes may further aggravate verticillium wilt.

Thresholds: Soil *Verticillium*, root knot and root lesion nematode counts, available from the Pest Diagnostic Clinic, University of Guelph, will help determine the need for control measures. See Appendix G, *Diagnostic Services*, on page 233.

Table 9–69. Pepper Disease and Insect Control Recommendations

Group Name (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
BACTERIAL LEAF SPOT						
inorganic (group M1)	copper hydroxide	Parasol Flowable	2.3–3.12 L	0.9–1.3 L	1	Apply at 7–10-day intervals.
		Kocide 2000	2.52–3.2 kg	1.0–1.3 kg	1	
FUNGAL DISEASES						
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	224–336 g	0	**Anthracnose and alternaria control.** Maximum 6 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group.
carboxamide (group 7)	boscalid	Lance WDG	175–315 g	70–126 g	0	**Botrytis grey mould and alternaria.** Use 420 g/ha (170 g/acre) to control botrytis grey mould. Maximum 5 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 4-hr re-entry.
inorganic salt	potassium bicarbonate	MilStop	2.8–5.6 kg	1.1–2.3 kg	0	**Powdery mildew.** Spray at 7-day intervals in 1,000 L/ha (10 gal/acre) of water. Use higher rates for heavier disease pressure. 4-hr re-entry.
APHIDS AND PEPPER MAGGOT						
carbamate (group 1A)	pirimicarb	Pirimor 50 DF	275–550 g	110–220 g	3	**Aphids only.**
organophosphate (group 1B)	dimethoate	Cygon 480	0.7–1.0 L	0.28–0.4 L	7	
		Lagon 480	0.7–1.0 L	0.28–0.4 L	3	
	diazinon[2]	Diazinon 50 W	0.5–1.0 kg	0.2–0.4 kg	5	**Aphids only.**
	acephate	Orthene 75 SP	750 g	300 g	7	Maximum 4 applications/yr.
	malathion	Malathion 500 E	1.25–2.75 L	0.5–1.1 L	3	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0–2.25 kg	0.4–0.9 kg	2	
		Thiodan 4 EC	1.5–2.75 L	0.6–1.1 L	2	
		Thionex 50 WP	1.1 kg	0.45 kg	2	
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	23–35 g	7	**Aphids only.** 12-hr re-entry.
EUROPEAN CORN BORER						
pyrethroid (group 3)	deltamethrin	Decis 5 EC	250–300 mL	100–120 mL	3	Maximum 3 applications/yr.
	permethrin	Pounce 384 EC	180 mL	73 mL	1	
carbamate (group 1A)	carbofuran	Furadan 480 F	1.1 L	0.45 L	2	48-hr re-entry. Maximum 3 applications/yr.
organophosphate (group 1B)	carbaryl	Sevin XLR	2.5–5.25 L	1.0–2.1 L	2	In areas where corn borer has been a problem, spray every 4 days.
	acephate	Orthene 75 SP	1.1 kg	0.45 kg	7	Do not use more than 4 applications/yr.
naturalyte (group 5)	spinosad	Success 480 SC	83 mL	34 mL	1	Use only on small larvae and low infestations. Maximum 2 applications/yr.
		Entrust 80 W	50 g	20 g	1	Maximum 2 applications/yr. Time application to target egg hatch or very small larvae. Maintain a spray water pH of 6 or greater.
CUTWORMS						
pyrethroid (group 3)	permethrin	Pounce 384 EC	180–390 mL	72–156 mL	1	Apply in the late evening or at night. Use high rates on dry or muck soils or on large larvae. Do not disturb soil for 5 days after treating.
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.48–0.96 L	40	24-hr re-entry.
		Pyrinex 480 EC	1.2–2.4 L	0.48–0.96 L	40	

[1] PHI = Pre-Harvest Interval.

[2] Control of aphids with diazinon has been inconsistent in many areas.

Management Notes: Follow a 4–6-year crop rotation. Do not rotate with related (solanaceous) crops, strawberries or raspberries. Keep fields clean of host weeds such as nightshades. Cultivars vary in tolerance to verticillium wilt. Soil fumigation may be required if verticillium and nematode counts are high. See the section *Nematodes*, on page 63.

VIRUSES (CUCUMBER MOSAIC VIRUS, TOMATO SPOTTED WILT VIRUS, ETC.)

Identification: Symptoms vary between viruses, cultivars and conditions. Interaction between viruses may occur, complicating visual diagnosis.

Development: Cucumber mosaic is spread by aphids. Thrips are a vector for tomato spotted wilt. The presence of these diseases usually follows periods of high aphid/thrips activity. Tomato mosaic virus is spread mechanically.

Management Notes: Control weed hosts such as pigweeds, nightshades and related weeds, milkweed, purslane and chickweed in and around the field. Spraying for aphids is not effective in controlling the common pepper viruses in Ontario. Tomato spotted wilt virus is rarely of economic concern. See also the section *Aphids*, on page 60.

Insects

CUTWORMS, TARNISHED PLANT BUG, WIREWORMS, APHIDS

For identification and management information on these common vegetable insects affecting peppers, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–69, *Pepper Disease and Insect Control Recommendations*, on page 149.

EUROPEAN CORN BORER

Identification: Larvae are greasy-looking, grey-to-tan-coloured, with small brown spots on each segment and a dark head. Full-grown borer larvae reach 2.5 cm (1 in.) in length. Adult moths are light brown with wavy lines across the wings. Larvae usually enter the fruit under the cap, leaving an entry hole with sawdust-like frass.

Period of Activity: Corn borers are present from mid-July through September. The second generation, and sometimes a partial third generation, attacks peppers. Peppers become susceptible to feeding when the fruit are the size of walnuts (3 cm ($1^{1}/_{4}$ in.) in diameter).

Thresholds: There is no tolerance for this pest in processing or fresh-market pepper crops. Use pheromone traps to monitor adult flight activity. Fields can also be scouted for egg masses and feeding activity, but damage is easy to miss.

Management Notes: Protect pepper fruit from fruit set until harvest if corn borers are active in the field. For effective chemical control, distribute spray material thoroughly. See Table 9–69, *Pepper Disease and Insect Control Recommendations*, on page 149.

For more information, see the OMAFRA Factsheet, *European Corn Borer in Sweet Corn and Other Horticultural Crops*, Order No. 97-019.

PEPPER MAGGOT

Identification: Larvae are legless, whitish-coloured and approximately 11–12 mm ($^{1}/_{2}$ in.) long. They do not have a distinct head. The amber-coloured adult flies have yellow and black markings. Females lay eggs in small fruit, creating a small dimple as the fruit sizes. Larvae feed inside the fruit. They are difficult to detect during scouting and grading.

Period of Activity: Pepper maggot activity is confined to the extreme southwest of Ontario and is of concern only in some years.

Thresholds: There is no tolerance for this pest in processing or fresh-market peppers. The presence of adults can be monitored with yellow sticky traps baited with a vial of ammonia. Visual assessments and sweep nets are also used to monitor adult populations.

Management Notes: If monitoring indicates a need, apply four sprays at 7-day intervals, starting the last week of June or first week of July. See Table 9–69, *Pepper Disease and Insect Control Recommendations*, on page 149.

Nematode Control

See the section *Nematodes*, on page 63.

Physiological Disorders

Blossom Drop

Pepper flowers or small fruit may abort and fall off, due to stressful growing conditions, including:

- daytime temperatures above 30°C–32°C (86°F–90°F) or below 15°C (59°F)
- nighttime temperatures above 21°C (70°F)

- dry weather
- excessive nitrogen
- tarnished plant bug injury
- variety sensitivity

Blossom-End Rot

In peppers, blossom-end rot may occur on the side of the fruit as well as at the blossom-end. See the section *Blossom-End Rot (BER)*, on page 204, for details on the causes and management of blossom-end rot.

Harvest and Storage

Harvest green peppers when the fruits are large and firm with a glossy skin. Coloured peppers can be harvested once full, ripe colour has developed. After harvest, wash fresh-market peppers in chlorinated water (100–150 ppm chlorine) to eliminate fruit rotting organisms. Green peppers can be held for 2–3 weeks at 7°C–13°C (45°F–55°F) at a relative humidity of 90%–95%. Fully ripe peppers have a shorter storage life.

See the section *Cooling and Storage*, on page 47.

POTATOES

Production Requirements

Potatoes are adapted to a wide range of soil conditions. The ideal potato soil is a deep, friable, well-drained, sandy loam, free from stones, pH of 6–7, containing adequate organic matter. Such a soil warms up quickly in the spring, holds water well and provides good aeration for the development of tubers. Because potatoes have shallow roots, a minimum of 2.5 cm (1 in.) of water per week is necessary to obtain good yield and quality. Sunny days and temperatures of 18°C–22°C (64°F–72°F) are optimum for vine growth and tuber development.

Cultivars

Table 9–70, *Potato Cultivar Descriptions*, on page 153, outlines the key characteristics of many potato varieties commonly grown in Ontario. Full variety descriptions are available at the Canadian Food Inspection Agency website: www.inspection.gc.ca/english/plaveg/potpom/var/indexe.shtml. For information on Ontario variety trials, contact the OMAFRA potato specialist.

The availability of seed for new or specialty cultivars can often be limited. To ensure a supply of seed, contract with your seed growers. For information on contracting and seed availability lists, contact the Ontario Seed Potato Growers Association at 8193 Main St. W., Everett, ON L0M 1A0, Tel: 705-435-5764.

Seed potatoes fall into seed classes, as shown in Table 9–71, *Canadian Seed Potato Classes*, on page 154.

Seeding Rate, Spacing and Depth

Row spacing is usually set at 90 cm (36 in.) Seed potatoes are planted near ground level and covered with 5–8 cm (2–3 in.) of soil by the planter.

A healthy 55-g (2-oz) seed piece will establish a vigorous plant. Plants from seed pieces smaller than 40 g (1.5 oz) are generally slower to emerge and have less vigour. Small seed pieces are also more likely to decay before the plant becomes established. Seed pieces cut larger than 55 g (2 oz) result in higher seed costs with little additional benefit.

Seed spacing is based on variety characteristics such as tuber set, resistance to hollow heart and resistance to the development of off-shaped tubers. Wider spacing (30–32 cm or 12–13 in.) is recommended for varieties with heavy tuber set, smooth tubers, resistance to hollow heart and low numbers of off-shaped tubers. Closer spacing (20–25 cm or 8–10 in.) is recommended for varieties with lower tuber set to reduce the number of oversized tubers.

Stand Establishment

Several physiological factors influence stand establishment:

Physiological Age of Seed: "Middle-aged" seed emerges faster than young or excessively old seed. The rate of aging depends on cultivar and temperature. Varieties can have short (CalWhite), intermediate (Superior) or long dormancies (Yukon Gold, Jemseg, Eramosa). The rate of aging increases with temperature. Old seed is desirable for the early crop. It emerges faster and more uniformly, sets and bulks tubers earlier, and matures faster than plants from young seed.

In long-season areas, the extended bulking period of young seed makes it desirable for the main crop. Old seed may result in lower yields of main crops as plants may be more stress prone.

Apical Dominance: The eye at the apical end of the tuber may inhibit other eyes from sprouting. The delay in emergence from non-apical buds will produce uneven stands when using cut seed from varieties with strong apical dominance such as Jemseg and Yukon Gold. Varieties with weak apical dominance, such as Superior, produce more uniform stands from cut seed.

Eye Distribution: Eye distribution on seed tubers is important. Some varieties have even eye distribution (Superior) while others have eyes concentrated at the apical end. When cut by machine, the latter varieties produce a large proportion of blind seed pieces. Large tubers accentuate the problem and should be graded out and cut by hand.

Check seed coming off the cutter frequently for size, blind pieces and slivers.

Seed Handling and Management

Plant Elite or Foundation Class seed to reduce leaf-roll, mosaic and bacterial diseases. Inspect seed on arrival for heating, freezing, grade and visual signs of tuber disease. Seed lots can be regraded by your local Agriculture and Agri-food Canada seed potato inspector. Requests for reinspection must be made within two working days of the receipt of the seed potatoes.

Table 9–70. Potato Cultivar Descriptions

Cultivar	Maturity	Tuber Type	Scab Tolerance	Comments
Tablestock: White Flesh				
Jemseg	very early	smooth, blocky	MR	Tubers oversize quickly. Susceptible to hollow heart. Susceptible to leaf roll and verticillium wilt. Immune to Virus X. Resistant to Virus Y and S.
Eramosa	very early	round-elongated, flattish	MS	Moderately susceptible to Virus Y. Prone to silver scurf in storage.
Envol	very early	smooth	VS	Lower yielding than Superior. Matures about 7 days earlier than Superior.
Superior	early	smooth	T	Susceptible to verticillium wilt and nematodes. Stress substantially reduces yields.
Onaway	early	rough, white skin	MT	Susceptible to blackleg, verticillium wilt, leaf roll and fusarium dry rot.
Cherokee	medium-early	very white skin, medium-deep eyes	T	Good keeper in storage. Misshapen tubers are a problem under adverse weather conditions.
Tablestock: Yellow Flesh				
Adora	early	oblong, light yellow, smooth skin	VS	Low dry matter content. Matures about 1 week later than Superior.
Yukon Gold	mid-season	round to elongated, pink eyes, smooth	VS	Emerges slowly. Use close plant spacings to avoid oversizing and hollow heart. Drought tolerant. Susceptible to air pollution.
Fabula	mid-season	uniform, large, plump, oval	T	Resistant to hollow heart. No culls. Requires low nitrogen.
Tablestock: Cream-Coloured Flesh				
Argos	late	oval, smooth skin, superficial eyes	MT	Tolerates low soil moisture. Do not apply excessive rates of nitrogen.
Tablestock: Red Skin				
Norland	early	smooth, oblong, slightly flattened; shallow eyes	T	Very susceptible to air pollution and moisture stress. Tubers are very susceptible to growth cracks when crop is under sudden stress. Do not use the herbicide metribuzin post-emergence.
Chieftain	late	smooth, round; very white flesh	MR	High yielding. Susceptible to heat necrosis, verticillium wilt, blackleg, Virus X and Y. The red skin tends to fade or scurf-over in some soils.
NorDonna	late	round with shallow eyes	MT	Holds colour well in storage. Susceptible to verticillium wilt. Susceptible to most common viruses.
Dual Purpose: Pre-Peel and Tablestock				
Shepody	mid-late	large, oblong, smooth; white flesh	VS	Do not use the herbicide metribuzin post-emergence. Susceptible to verticillium wilt. Does not perform well in Southwestern Ontario. Susceptible to Virus Y and S.
CalWhite	mid-late	oblong, large with buff-coloured skin and very white flesh	VS	Very vigorous vine and thick stems. Use close plant spacings to avoid oversizing and hollow heart. Susceptible to leaf roll and net necrosis. Sensitive to metribuzin.
Goldrush	late	smooth golden-russet skin, white flesh	T	Very susceptible to early blight. Very susceptible to most viruses. Resistant to hollow heart.
Kennebec	late	elliptical to oblong; smooth, creamy buff skin; thin-skinned	S	Avoid excess nitrogen. Use close plant spacings to avoid oversizing. Tubers are very susceptible to greening. Very susceptible to verticillium wilt and pink eye. Resistant to Virus A and Y.
Gourmet or Specialty Market				
All Blue	mid-late	blue skin and flesh	S	Prone to silver scurf.
German Butterball	mid-late	oval with dark yellow flesh	S	High yield. Excellent flavour.
Banana	late	long, thin fingerling; yellow skin and flesh	S	Good yielder. Excellent flavour.

Scab tolerance:
VS = Very Susceptible
MS = Moderately Susceptible
S = Susceptible
MT = Moderately Tolerant
T = Tolerant
MR = Moderately Resistant
R = Resistant

Request at least two certification tags with each bulk load — one for your bin and one for your files. The tag number gives you direct access to the seed grower. Handle, store and plant the seed carefully. Poor stands and field performance are not always the seed grower's fault.

To help prevent disease, discard all tubers and seed pieces showing signs of rot. Follow good sanitation practices in storage areas and on all knives, containers and handling equipment. For more information, see the section *Storage Sanitation*, on page 50.

Table 9–71. Canadian Seed Potato Classes

Class	Field Generation[1]
Nuclear	Greenhouse Laboratory
Pre Elite	1
Elite I	2
Elite II	3
Elite III	4
Elite IV	5
Foundation	6
Certified	7

[1] Seed drops a class each year in the field if it passes inspection.

Pad all seed-handling equipment as you would harvest equipment. Reduce drops to less than 15 cm (6 in.) to minimize bruising. Ensure that cutter knives are sharp. Cold storage temperatures make seed tubers more sensitive to bruising. Warm seed to at least 5°C–10°C (40°F–50°F) prior to handling. Bruising acts as an entry site for pathogens leading to seed piece decay. Mishandling may physiologically age seed, leading to more stems per plant, smaller tubers and more stress susceptibility.

Cut seed not being planted immediately should be given special attention to ensure healing and suberization by:

- forced-air circulation through the shallow pile
- temperatures of 10°C–15°C (50°F–59°F)
- high relative humidity of 90%–95% (prevent free water from forming on tuber surfaces)

Maintain these conditions for 3–4 days. After this, temperature may be lowered, but humidity must be maintained and fans run intermittently.

Never allow cut seed to stand in the hot sun or in drying wind. This causes minute cracks in the skin that allow bacteria and fungi to establish. Do not plant seed tubers that have been washed.

Seed Piece Treatments

Serious problems with seed piece decay are often related to adverse weather during the planting season. Fungal seed piece decay is usually caused by several species of the fungus *Fusarium*. These pathogens need wounds to enter the seed piece.

There may be little benefit from seed piece treatments if soil conditions are optimal during planting and crop emergence. However, if unfavourable environmental conditions develop soon after planting, treated seed usually produces a better stand. Seed treatments may also help in managing other diseases, including rhizoctonia canker, late blight and blackleg.

Mancozeb, the active ingredient of some *Fusarium* seed treatments, also protects healthy seed pieces against late blight. The late blight fungus can produce spores on cut surfaces of infected tubers in 24 hr. These spores will infect healthy seed pieces. Seed treatments that do not contain mancozeb, such as Maxim and Senator, do not protect healthy seed against late blight infection. Mancozeb does not cure existing late blight infections; it only prevents new infections.

Gypsum-based coatings act as a drying agent but have no insecticidal or fungicidal activity. Seed treatments are usually dusted onto cut seed as it moves along the conveyor. The seed may then be moved through a rotating drum apparatus to distribute the treatment more evenly. Check the applicator often to be certain that the treatment is being applied at the labelled rate.

See Table 9–72, *Potato Seed Piece Treatment Recommendations*, below.

Do not plant seed lots that are known to be infected with late blight.

Table 9–72. Potato Seed Piece Treatment Recommendations

Group	Common Name	Trade Name	Rate/50 kg seed	Pests Controlled
benzimadazole	thiophanate-methyl	Senator PSPT	250 g	Seed decay.
dithiocarbamate	metiram	Polyram 16 D	225–325 g	Seed decay.
	mancozeb	Tuberseal	250 g	Seed decay.
		Potato ST 16	250 g	Seed decay.
phenylpyrrole	fludioxonil	Maxim PSP[1]	250 g	Seed decay.
neonicotinoid	imidacloprid	Admire SPT	13–19.5 mL	Colorado potato beetle, potato flea beetle, potato leafhopper, aphids[2].
		Alias 240 EC		

[1] Maxim treatments may increase the number of stems, leading to smaller tuber size, on the varieties Shepody and Atlantic.

[2] Do not make subsequent foliar or in-furrow applications of imidacloprid or other related insecticides following seed treatment with imidacloprid. Plant back restrictions apply. See the label for more information.

Chitting or Green Sprouting

This process may be used for limited plantings, where early emergence and yield are important, or in short-season areas. Chitting is the process of aging seed in the light to control sprout growth, resulting in earlier emergence and sizing. Chitting will take several weeks, so plan well ahead of the expected planting date.

Small, whole seed is placed in shallow containers, 2–3 tubers deep. Air movement and light penetration are essential. Seed can be chitted in a building with fluorescent lights or by natural light in a greenhouse. Short, stubby, dark-green sprouts are desirable to minimize sprout damage at planting.

Chitting seed in cool temperatures (such as 8°C or 48°F) under fluorescent light results in shorter sprouts than using warmer temperatures. Seed taken from winter storage of 3°C–4°C (37°F–39°F) will require about 250 degree-days (base 4°C). For the degree day (DD) calculation, see the section *Growing Degree Days*, on page 32.

If the daily maximum temperature is 15°C and the daily minimum temperature is 5°C, using the 4°C base, it would take approximately 41 days (250 DD / 6) to green-sprout the tubers.

Plant green-sprouted tubers with cup or bell planters to reduce the chances of injuring the sprouts. Avoid pick planters. Sized seed will improve the uniformity of emergence.

If a greenhouse is unavailable, seed can be chitted at 20°C (68°F) in natural shaded light for about 2 weeks with similar results. The same can be accomplished inside a heated building. Higher levels of fluorescent light are required than at cool temperatures. In all cases, provide sufficient humidity to prevent dessication but not enough to stimulate rooting.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

See Table 9–73, *Potato Nitrogen Recommendations*, right. If the total nitrogen-plus-potash applied is over 360 kg/ha (320 lb/acre), broadcast at least a portion before planting to avoid concentrating the fertilizer band near the seed piece and potato roots. Broadcasting or side-dressing nitrogen after potatoes are 20 cm high is not generally recommended, as it may delay maturity.

Table 9–73.
Potato Nitrogen Recommendations

Soil	Actual N		Expected Marketable Yield
	kg/ha	lb/acre	t/ha
Mineral main crop	50	45	15
	75	67	20
	130	116	25
	200	178	30+
Mineral early crop	70	62	
Muck early and main crop	up to 60	53	

Phosphorus

Soil tests are required to determine phosphorus requirements. Where the soil test values are 51 mg P per L soil (ppm) or higher on mineral soils, phosphate applications may be reduced to 30 kg/ha (28 lb/acre). For soils testing lower than 51 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

On muck soils with soil test P values of 61 mg P per L soil, potatoes are unlikely to respond to additional phosphorous applications. For muck soils testing lower than 61 mg P per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

On mineral soils testing medium or low for phosphate, place some or all of the phosphate fertilizer in bands 2.5 cm (1 in.) below and 6 cm (2½ in.) to each side of the seed piece at planting time. On muck soils or on mineral soils testing high for phosphate, placement is less critical and fertilizer may be broadcast.

Potassium

Soil tests are required to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, potatoes are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, or Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Many of the sandy loam soils commonly used in potato production are especially prone to organic matter degradation, wind and water erosion. For tips on how to maintain and improve soil quality, see Chapter 2, *Soil Management*, on page 21.

Table 9–74.
Potato — Interpretation of Plant Analysis

Values apply to the fourth leaf, including stem, from the growing tip sampled at early bloom.

Nutrient	Units	Critical Concentration[1]	Maximum Normal Concentration[2]
Nitrogen	%	2.50	3.50
Phosphorus	%	0.15	0.50
Potassium	%	1.20	2.50
Calcium	%	1.50	
Magnesium	%	0.10	0.60
Sulphur	%	0.14	
Boron	ppm (µg/g)	2.0	25.0
Copper	ppm	2.0	25.0
Manganese	ppm	15.0	150.0
Zinc	ppm	14.0	70.0

[1] Yield loss due to nutrient deficiency is expected with nutrient concentrations at or below the "critical" concentration.

[2] Maximum normal concentrations are more than adequate but do not necessarily cause toxicities.

Petiole/Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information, see the section, *Plant Analysis*, on page 3.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. Samples for plant analysis should be taken, in the morning, at early bloom. Sample at least 50 plants distributed throughout the chosen area. Take the fourth leaf from the tip, including the petiole. Sample problem areas separately. See Table 9–74, *Potato — Interpretation of Plant Analysis*, left.

Integrated Pest Management

Diseases

Practice a suitable crop rotation to prevent build-up in the soil of organisms causing verticillium wilt, *Rhizoctonia* diseases, common scab and early blight. Follow a broadspectrum protectant fungicide program, starting no later than row closure. See Table 9–75, *Broad Spectrum Protectant Fungicide Recommendations*, below.

SEED-PIECE DECAY

See the section *Seed Handling and Management*, on page 152. ***Note:*** Seed piece treatments will not control bacteria.

EARLY BLIGHT

Identification: Dark brown-to-black spots develop on infected leaves. The spots are often irregular in shape with concentric rings. Lesions are frequently surrounded by a narrow yellowish border. Symptoms appear first on the older leaves of mature plants, spreading to the younger leaves under favourable weather conditions. Infected tubers develop dark brown-to-black, slightly sunken external lesions.

Development: Temperatures between 17°C–24°C (63°F–75°F) and 12 hr of leaf wetness favour early blight development. Spores are further spread by alternating periods of wet and dry weather. Humidity is needed for spore germination. Dry weather promotes the release of spores and wind dissemination.

Tuber infection occurs at harvest, primarily through cuts, bruises or wounds. Symptoms may appear after the potatoes have been stored for several months.

Table 9–75.
Broad Spectrum Protectant Fungicide Recommendations

Start spraying prior to row closure.

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
chloronitrile (group M5)	chlorothalonil	Bravo 500	1.2–2.4 L	0.5–1.0 L	1	Use high rate under severe disease pressure. Use higher rates as the crop canopy closes.
dithiocarbamate (group M3)	mancozeb	Manzate Pro-Stick	1.1–2.25 kg	0.44–0.9 kg	1	Use high rate under severe disease pressure. Use higher rates as the crop canopy closes.
		Dithane DG				
		Penncozeb 80 WP				
	metiram	Polyram DF	1.1–2.25 kg	0.44–0.9 kg	1	24-hr re-entry. Use high rate under severe disease pressure. Use higher rates as the crop canopy closes.

[1] PHI = Pre-Harvest Interval.

Management Notes: Begin the fungicide program early and ensure adequate coverage of the lower leaves. Stress conditions such as drought, insect damage, air pollution and rapid growth at tuber sizing increase the plant's susceptibility to early blight. Under these conditions, spray intervals should be shortened to 7 days. Plants infected with *Verticillium* or expressing common mosaic symptoms are particularly susceptible to early blight. See Table 9–76, *Early Blight and Late Blight Protectant Fungicide Recommendations*, on page 158.

LATE BLIGHT

If late blight is suspected in the seed, apply Curzate 60 DF + Manzate Pro-Stick at 95% crop emergence.

Identification: Initial symptoms on leaves are small, light-to-dark green, circular-to-irregular shaped, water-soaked spots. Later, the lesions become grey-to-tan, surrounded by a light green halo. White and fuzzy mycelium develop at the edge of the lesions, usually on the underside of leaves. Under humid conditions, entire leaves can become blighted as new infections occur and existing lesions coalesce.

Late blight lesions on tubers are irregularly shaped, brown-to-purplish and slightly sunken. The size of the tuber lesions is variable. A reddish-brown, granular dry rot develops under the skin, penetrating less than 1.25 cm (1/2 in.) into the tuber. Following late blight infection, secondary bacteria infect the tubers, causing a slimy and foul-smelling rot.

The late blight fungus has two mating types, A1 and A2. Only a laboratory analysis can determine which mating type and strain are infecting a crop. Field identification is limited to "late blight." If the two mating types infect the same potato plant tissue and mate, oospores (sexual spores) are produced. Oospores are thick walled and survive in the soil for several years in a dormant state. Oospores can initiate soil-borne late blight infections. In Ontario, the presence of oospores in potato fields has not been detected.

Development: The late blight fungus overwinters in infected cull tubers, tubers left in the field after harvest, and in infected seed tubers. The disease develops inside the stems and foliage of plants grown from infected tubers. Temperatures of 12°C–20°C (54°F–68°F), coupled with leaf wetness for a few hours are ideal to initiate sporulation of the fungus on infected plants. Spores are dispersed by wind. They germinate in the presence of free water and penetrate leaves, stems and petioles, initiating new infections. Disease symptoms develop 4–6 days after infection.

Management Notes: Start a preventative fungicide program, before row closure. Keep all foliage and newly formed leaves covered. It is critical to time spray applications so the crop is protected before infection periods or periods of wet weather occur. See *Late Blight*, on page 158.

- Plant healthy seed. Tagged seed (Elite or Foundation) gives no guarantee it is not carrying late blight.
- Use a seed treatment containing mancozeb.
- Destroy cull piles (bury, chop, freeze or feed to livestock) prior to new crop emergence. Monitor cull disposal sites and treat emerging sprouts with herbicide.
- Control volunteer potatoes and host weeds growing in neighbouring fields.
- Create a good hill that ensures good tuber coverage.
- Control weeds. Weeds increase the humidity within the potato canopy, favouring the development of late blight.
- If possible, irrigate during the day to avoid prolonged periods of wet foliage at night. Do not irrigate near the end of the season if new outbreaks of late blight are noticed.
- Scout fields twice a week. Pull, bag and remove the first infected plants found. Mark these areas with a flag and recheck.
- Disc in or top-kill any late blight hot-spots immediately.
- Once the disease has been detected in the field, apply copper sprays to kill late blight spores on the soil that might otherwise be washed into the tubers.
- Seal soil cracks to reduce tuber infection.
- Harvest when vines are completely dead so living spores are not sprinkled on tubers at harvest.
- Sort tubers coming into storage. Remove damaged and decaying tubers.
- Monitor the storages frequently. Look for water condensation on the walls and ceiling. Keep the temperature and the humidity at the lowest possible levels to reduce the spread of late blight in storage.

Table 9–76.
Early Blight and Late Blight Protectant Fungicide Recommendations

(begin applications prior to disease development)

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
EARLY BLIGHT ONLY						
QoI (group 11)	pyraclostrobin	Headline EC	450–670 mL	180–268 mL	3	Rotate with a product from a different fungicide family after every application. 48-hr re-entry.
	azoxystrobin	Quadris Flowable	500–800 mL	200–320 mL	1	Maximum 3 applications/yr. Do not apply sequential applications of any QoI fungicide or of any tank-mix containing a QoI fungicide.
QoI + chloronitrile (group 11 + M5)	azoxystrobin + chlorothalonil	Quadris Flowable + Bravo 500	500 mL + 2L	200 mL + 800 mL	2	Maximum 3 applications/yr. Do not apply sequential applications of any QoI fungicide or of any tank-mix containing a QoI fungicide.
anilino-pyrimidine + chloronitrile (group 9 + M5)	pyrimethanil + chlorothalonil	Scala 400 SC + Bravo 500	750 mL + 1.2–2.4 L	300 mL + 0.5–1.0 L	7	Maximum 6 applications/yr.
carboxamide (group 7)	boscalid	Lance WDG	175–315 g	70–126 g	30	Do not apply more than 2 applications before rotating to a different fungicide family. 4-hr re-entry.
EARLY AND LATE BLIGHT						
QoI + dithiocarbamate (group 11 + M3)	fenamidone + mancozeb	Reason 500 SC + Manzate Pro-Stick	200 mL + 1.25 kg	80 mL + 0.5 kg	14	Do not apply sequential applications of any QoI fungicide or of any tank-mix containing a QoI fungicide.
		Reason 500 SC + Dithane DG	200 mL + 1.17 kg	80 mL + 0.47 kg		
		Reason 500 SC + Penncozeb 80 WP	200 mL + 1.17 kg	80 mL + 0.47 kg		
QoI + chloronitrile (group 11 + M5)	fenamidone + chlorothalonil	Reason 500 SC + Bravo 500	200 mL + 1.25 L	80 mL + 500 mL		Do not apply sequential applications of any QoI fungicide or of any tank-mix containing a QoI fungicide.
QoI + acetamide (group 11 + 27)	famoxadone + cymoxanil	Tanos 50 DF	560–840 g	224–336 g	14	24-hr re-entry. Do not apply sequential applications of any QoI fungicide or of any tank mix containing a QoI fungicide.
QoI + chloronitrile (group 11 + M5)	pyraclostrobin + chlorothalonil	Headline EC + Bravo	450–670 mL + 1.2–2.4 L	180–268 mL + 0.5–1.0 L	3	Rotate with a product from a different fungicide family after every application. 48-hr re-entry.
QoI + dithiocarbamate (group 11 + M3)	pyraclostrobin + metiram	Headline EC + Polyram	450–670 mL + 1.1–1.75 kg	180–268 mL + 440–700 g	3	Rotate with a product from a different fungicide family after every application. 48-hr re-entry.

[1] PHI = Pre-Harvest Interval.

Late Blight

Late blight has the potential to be an extremely destructive disease of potatoes in Ontario. Effective late blight control starts with a preventative spray program starting before row closure. The best management programs include broad spectrum, protectant and targeted fungicides. Always rotate between chemical groups.

The broad spectrum fungicides are listed in Table 9–75, *Broad Spectrum Protectant Fungicide Recommendations*, on page 156.

See Table 9–76, *Early Blight and Late Blight Protectant Fungicide Recommendations*, above, for a full list of protectant fungicides recommended for early and late blight.

Table 9–77.
Late Blight Targeted Protectant Fungicide Recommendations

Begin applications when weather conditions favour late blight, or if late blight is identified in the local area.

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
carbamate/ chloronitrile (group 28/M5)	propamocarb/ chlorothalonil	Tattoo C	2.7 L	1.1 L	7	Use 200–300 L water per ha (20–30 gal/acre). Maximum 3 applications/yr. 24-hr re-entry.
QiI (group 21)	cyazofamid	Ranman 400SC	100–200 mL	40–80 mL	7	Maximum 6 applications/yr. Do not make sequential applications. 12-hour re-entry. 30-day plant-back interval. Use high rate for tuber blight protection.
acetamide + dithiocarbamate (group 27 + M3)	cymoxanil + mancozeb	Curzate 60 DF + Manzate Pro-Stick	225 g + 1.6 kg	90 g + 0.65 kg	8	Make 2 applications, 5 days apart, then rotate with a late blight targeted protectant fungicide from a different chemical family. 24-hr re-entry.
benzamide + dithiocarbamate (group 22 + M3)	zoxamide + mancozeb	Gavel 75 DF	1.7–2.25 kg	0.68–0.9 kg	3	Maximum 6 applications/yr. Plant-back restrictions apply, see label for details. 48-hr re-entry.
pyridinamine (group 29)	fluazinam	Allegro 500 F	400 mL	160 mL	14	24-hr re-entry. Do not make more than 3 sequential applications.
cinnamic acid + chloronitrile (group 40 + M5)	dimethomorph + chlorothalonil	Acrobat 50 WP + Bravo 500	450 g + 1.2–2.4 L	180 g + 0.5–1.0 L	14	Maximum 3 applications/yr. 120-day plant-back interval. Apply after top kill for tuber blight protection.
cinnamic acid + dithiocarbamate (group 40 + M3)	dimethomorph + mancozeb	Acrobat 50 WP + Dithane DG	450 g + 1.1–2.25 kg	180 g + 0.44–0.9 kg	14	
	dimethomorph + metiram	Acrobat 50 WP + Polyram	450 g + 1.1–2.25 kg	180 g + 0.44–0.9 kg	14	
LATE BLIGHT TUBER INFECTION PROTECTION						
inorganic (group M1)	copper hydroxide	Kocide 2000	0.8–1.6 kg	0.32–0.65 kg	1	Combine with 1.75–2.25 kg/ha (0.7–0.9 kg/acre) Manzate Pro-Stick. Use 2.4 kg/ha (1 L/acre) at vinekill.
		Parasol Flowable	0.8–1.8 L	0.32–0.72 mL	1	
	copper sulphate	Copper 53W	5.5 kg	2.2 kg	1	Copper sulphate can cause phytotoxicity, especially under hot and humid conditions. Apply close to vine killing time to kill spores of the late blight fungus.
	copper oxychloride	Copper spray	4 kg	1.6 kg	1	

[1] PHI = Pre-Harvest Interval.

The strains of the late blight fungus that now prevail in Ontario are more aggressive and develop faster than in the past. If the weather is favourable for disease development and no effective fungicides are applied, late blight can destroy a potato field within a few days.

If the weather is cool and wet, new growth should be protected against late blight at all times, even if late blight has not been found in the area. Adjust spray intervals accordingly. A 4–5-day spray interval may be necessary if the crop is growing vigorously.

Under cool, wet conditions, or if late blight has been found in the local area, use one of the fungicides listed in Table 9–77, *Late Blight Targeted Protectant Fungicide Recommendations*, above.

If you have found late blight in your fields, make two applications of Curzate 60 DF tank-mixed with Manzate Pro-Stick or Bravo 500, 5 days apart. Curzate 60 DF has a 36-hr kick-back. It will kill newly germinated spores for up to 36 hr after the initial infection. After the second application of Curzate 60 DF, switch to one of the other late blight targeted protectant fungicides listed in Table 9–77, above.

Table 9–78.
Potato
Pythium Leak, Pink Rot, Rhizoctonia and Fusarium Dry Rot Control

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
In-Furrow						
phenylamide (group 4)	metalaxyl-M	Ridomil Gold 480 SL	4 mL per 100 m of row	4 mL per 328 ft of row	80	**Pink rot** Apply directly over the seed pieces in-furrow.
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL per 100 m of row	4–6 mL per 328 ft of row	90	**Rhizoctonia stem canker, stolon canker, black scurf and silver scurf control.** Apply once at planting in 50–140 L of water/ha (5–14 gal/acre) 30-day plant-back restrictions.
Foliar						
phenylamide + dithiocarbamate (group 4 + M3)	metalaxyl-M + mancozeb	Ridomil Gold MZ 68WP	2.5 kg	1 kg		Mancozeb, the protectant fungicide in this mixture, should also provide protection against early and late blight. Do not use more than 3 times per year.
phenylamide + chloronitrile (group 4 + M5)	metalaxyl-M + chlorothalonil	Ridomil Gold + Bravo Twin Pak	2.21 L (1 jug/4 ha)	0.88 L (1 jug/10 acre)		Do not use more than 3 times per year.
Post-Harvest						
dithiocarbamate (group M3)	mancozeb	Dithane F-45	1.58 L per 1,000 kg of seed			Apply to **seed potatoes only** prior to storage to control fusarium dry rot.
inorganic (group M1)	hydrogen peroxide	StorOx	100 mL per 10 L water			**Fusarium dry rot suppression only.** Apply prior to storage.

[1] PHI = Pre-Harvest Interval.

FUSARIUM DRY ROT

Identification: Sunken or wrinkled areas develop on the surface of tubers. A dark brown-to-black dry decay develops internally.

Development: Bruising or wounding of tubers during harvest or handling favours fusarium dry rot infection. The leading cause of potato seed piece breakdown after planting is fusarium dry rot.

Management Notes: A "bag test" is recommended on seed stock after 1 or 2 months of storage to assess the fusarium dry rot concentration. Select 20 tubers from the face of the pile, cut them in quarters if small or in eighths if larger and drop them in a new 10-lb potato bag. Shake the bag vigorously for a minute to inoculate the freshly cut seed. Fold the paper bag over loosely and place it inside a plastic garbage bag. Store in a cool (16°C–18°C (61°F–64°F)), dark location for 3–4 weeks. If more than 30% of the seed pieces show fusarium dry rot infection, there is a potential high incidence of seed piece decay. See Table 9–72, *Potato Seed Piece Treatment Recommendations*, on page 154, and Table 9–78, *Potato Pythium Leak, Pink Rot, Rhizoctonia and Fusarium Dry Rot Control*, above.

RHIZOCTONIA

Identification: Typical symptoms of *Rhizoctonia* diseases include stem and stolon cankers, aerial tubers, leaf rolling, premature death of plants and tuber malformations. Black sclerotia (scurf) development on infected tuber surfaces causes serious losses for tablestock growers.

Development: Rhizoctonia is a common seed- and soil-borne fungus. It is more prevalent during cool, wet springs.

Management Notes: Rhizoctonia populations increase in soil where little or no rotation is practised. Avoid land known to be heavily infested with *Rhizoctonia*. Use clean seed, free of black scurf. See Table 9–78, *Potato Pythium Leak, Pink Rot, Rhizoctonia and Fusarium Dry Rot Control*, above.

VERTICILLIUM WILT

Identification: Symptoms are usually noticeable after flowering. Infected stems often wilt during the heat of the day but recover at night. The vascular area or "woody tissue" of infected stems turns brown. As the disease progresses, the foliage turns yellow. The crop dies early, 3–4 weeks before reaching maturity. Tubers do not size, and serious yield losses occur. The presence of root lesion nematodes can further aggravate verticillium wilt.

Development: Verticillium wilt persists in the soil for many years. Short crop rotations with susceptible varieties tend to increase the population of *Verticillium* to damaging levels, especially in sandy soils. Verticillium wilt symptoms are increased by crop stress induced by high soil temperatures, drought, nutrient deficiencies and insect damage.

Management Notes: Test soils for *Verticillium* levels. If *Verticillium* and/or nematode levels are high, fumigation may be necessary. See Appendix G, *Diagnostic Services*, on page 233. Follow a long-term rotation with non-host crops. Plant cereal cover crops after early potatos to control weed hosts, such as nightshade. Good soil management promotes stronger, healthier potato roots.

PYTHIUM LEAK

Identification: Infected tubers develop a cream-to-black watery rot. The rotted flesh is clearly separated from healthy tissue by a dark line. A clear, brownish liquid is readily released by the rotted tissue when the tuber is pressed. Pythium leak rot has a sweet smell.

Development: *Pythium* fungi are common to many different crops and soils. Tubers are infected through cut surfaces or bruises that occur at harvest. Pythium leak is particularly troublesome in immature potatoes harvested under warm conditions. Serious losses can also occur when tubers are handled roughly, and when crops are stored at high temperatures with poor ventilation. Pythium leak can also be a problem on cut seed in the field.

Management Notes: Minimize mechanical injury to the tubers during digging, grading and storage operations. Do not harvest when the weather is too hot. Cool tubers immediately after harvest and maintain good air movement in the storage area. See Table 9–78, *Potato Pythium Leak, Pink Rot, Rhizoctonia and Fusarium Dry Rot Control*, on page 160.

PINK ROT

Identification: Pink rot causes a soft, spongy rot on tubers. On exposure to the air, the infected flesh develops a pink colour and eventually turns completely black. Internal rot usually begins at the stem end and is creamy-coloured or light brown. Wilt symptoms can occur on the foliage.

Development: Infection usually occurs before harvest. This disease is associated with excessive soil moisture, low spots in the field, over-irrigated areas and poorly drained soils. Pink rot may spread slowly in storage.

Management Notes: The varieties Russet Norkotah, Goldrush, Snowden and Kennebec are all very susceptible to pink rot. See Table 9–78, *Potato Pythium Leak, Pink Rot, Rhizoctonia and Fusarium Dry Rot Control*, on page 160.

BLACKLEG

Identification: Infected seed and sprouts often rot before or soon after emergence, resulting in uneven stands. If the spring weather favours rapid emergence, infected seed will produce weakened, stunted plants. Infected stems show an inky black decay extending up from the infected seed piece. Leaves tend to roll upward at the margins.

Development: The blackleg bacterium is primarily seed-borne. Wet weather and excessive soil moisture favour disease development.

Management Notes: Plant higher generation seed. Poor sanitation and seed-cutting practices may increase blackleg incidence. Disinfect cutting knives often during seed cutting. Monona and Chieftain varieties are very susceptible to blackleg.

COMMON SCAB

Identification: Round, brown spots develop on the tubers. As tubers increase in size, the lesions expand and scab severity increases. Lesions may be corky and raised, or pitted.

Development: Warm, dry soils during and after tuber-set are conducive to scab development. A soil pH from 6–7.5 is most favourable for common scab. The acid-tolerant scab species (*S. acidiscabies*) can infect tubers in soils with pH as low as 5.

Management Notes: Avoid planting scabby seed. If possible, choose tolerant cultivars such as Superior, Cherokee, Onaway, Norland and Pike. Avoid heavy applications of limestone. Where irrigation is available, maintain high soil moisture for 4 weeks after tuber setting begins. Recent research has shown that application of organic amendments reduces the incidence of scab.

BACTERIAL RING ROT (BRR)

Identification: The type of symptoms expressed by BRR vary depending on the variety. Infected plants may not show symptoms if the weather is cool and wet. The leaflet tissues turn yellow between the veins. Stems and leaves wilt. Infected tubers develop a creamy-brown, cheesy, odourless rot.

Development: Ring rot develops rapidly when soils are dry and temperatures range from 24°C–32°C (75°F–90°F). The ring rot bacterium can survive for up to 2 years as dried slime on cutting knives, storage bins, equipment, bags, etc.

Management Notes: Use tagged seed that has had a BRR lab test. Practice complete cleanliness. (See the section *Storage Sanitation*, on page 50.)

Zero tolerance control measures are in place against this disease. The seed potato regulations in Canada indicate that upon a finding of bacterial ring rot, all lots under cultivation by the grower are rejected for certification.

LEAF ROLL AND NET NECROSIS

Identification: Seed-borne infections cause stunted plants with rolled-up lower leaves. Affected leaves are pale and have a leathery texture. Lower leaves eventually die, and upper leaves turn yellow. Yield is reduced in both tuber numbers and tuber size.

Aphid-transmitted infections have similar but less severe symptoms. In some varieties, notably Russet Burbank and CalWhite, late-season infections may cause net necrosis in daughter tubers, rendering them unmarketable. Shepody is slightly susceptible.

Development: Several species of aphids can transmit the leaf roll virus, but the green peach aphid seems to be the most common vector. Infected seed, sprouted cull potatoes and volunteers are the main overwintering sources of leaf roll. Winged aphids spread the virus over long distances.

Management Notes: Control aphids by scouting fields and spraying. Use varieties resistant to net necrosis. Plant tagged seed indicating low or absent levels of this disease.

Physiological Disorders

PINK EYE

For many years, pink eye was thought to be caused by bacteria. However, recent scientific reports suggest that pink eye is a physiological disorder.

Pink eye is characterized by skin-deep, pinkish blotches near the eyes of the stem end. The skin of affected tubers dries and cracks easily. Internal reddish-brown to black discolouration, cavities and secondary soft rots are often associated with severe pink eye. Pink eye occurs sporadically. It usually develops late in the growing season under conditions of high soil moisture.

Management Notes: Increase air flow through the pile to promote drying of pink-eye lesions. Pink eye is often associated with *Verticillium* and *Rhizoctonia*. Good control of these fungi will reduce the incidence of pink eye. Varieties such as Kennebec and Superior are very susceptible to pink eye.

BROWN CENTRE AND HOLLOW HEART

Brown centre is associated with cool, wet soil conditions during tuber initiation and/or periods of rapid tuber growth. Pith tissues near the centre of the tuber become light-to-dark brown. The affected cells eventually die.

Hollow heart is common in oversized or rapidly growing tubers. A single large cavity or several smaller cavities develop in the tuber. Cavity size can range from less than 1 cm to a large area that includes the whole pith tissue. This disorder is more severe under conditions that favour rapid tuber enlargement, such as fluctuating soil moisture levels. Wide plant spacings can increase the incidence of hollow heart. The varieties Atlantic and Yukon Gold are very susceptible to hollow heart.

HEAT NECROSIS

Heat necrosis occurs when a period of slow tuber growth is followed by sudden, high temperatures. Tubers develop round or irregular necrotic spots or blotches in the vascular tissue area. Affected tissue ranges from light tan or reddish-brown to rust-coloured. There are no external symptoms of heat necrosis. The varieties Atlantic and Chieftain are very susceptible to heat necrosis.

Insects

WIREWORMS, APHIDS, CUTWORMS, TARNISHED PLANT BUG

For identification and management information on these common vegetable insects affecting potatoes, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–79, *Potato Insect Control Recommendations*, on page 164.

COLORADO POTATO BEETLE

Identification: Bright-yellow eggs are laid in clusters, usually on the underside of leaves. Larvae are orange-red with a distinct black head, humped back and a double row of black dots on each side of their bodies. Adult potato beetles are orange with 10 black stripes on their wings.

Period of Activity: In Ontario, the Colorado potato beetle (CPB) usually completes two generations during the growing season. In warm summers, a third generation may develop.

Adult beetles overwinter in the field or in surrounding, protected areas. Egg-laying occurs shortly after emergence. If spring weather is warm, beetle emergence is often very rapid. During cool springs, beetle emergence becomes more staggered. Females lay eggs for a 4–5-week period.

Eggs hatch into larvae within 4–9 days, depending on temperature. The larvae pass through 4 stages (instars), reaching maturity in 7–20 days. The pupal stage lasts 5–9 days, after which the next generation of adults emerges. The second-generation beetles feed continuously to accumulate enough energy to survive the winter buried in the soil.

Thresholds: One adult or larvae per plant.

Management Notes: This insect has developed resistance to most of the insecticides registered for its control. See the section *Resistance Management*, on page 54.

To delay the development of resistance in CPB populations, rotate fields so that beetles must walk or fly from overwintering sites to newly planted fields. This takes time, and many beetles die before reaching the new crop. Plastic-lined ditches may be used to trap emerging adults as they walk towards the potato crop from overwintering sites. Propane flamers may also be used on border rows or whole fields until the crop is 15 cm (6 in.) high.

Small CPB larvae are much easier to control than adult beetles or large larvae. See Table 9–80, *Potato Colorado Potato Beetle Control Recommendations*, on page 165.

Dip tests are recommended before spraying any insecticide because of the high levels of resistance found in CPB populations. Dip tests are very effective in determining which insecticide should provide the best control in your fields.

POTATO LEAFHOPPER

Identification: The adult leafhopper is yellow-green, wedge-shaped and approximately 3 mm long. Immature nymphs are smaller and wingless. When disturbed, leafhoppers quickly move forward or sideways. Both the adults and the nymphs feed on potatoes, causing leaf puckering and browing of the leaf margins ("hopperburn"). Hopperburn is often confused with drought stress.

Period of Activity: Leafhoppers migrate to Ontario in the early spring. Initial generations feed on alfalfa before moving into other crops, such as potatoes.

Thresholds: 0.5 nymphs or adults per plant.

Management Notes: Leafhopper populations can increase rapidly in warm weather. Field scouting is the first line of defence against this insect. Where potatoes are planted in the vicinity of an alfalfa field, scout twice weekly. See Table 9–79, *Potato Insect Control Recommendations*, on page 164.

Nematode Control

See the section *Nematodes*, on page 63, for control recommendations.

Sprout Inhibition

After completion of a rest (dormancy) period, potatoes sprout readily. Potatoes treated with chemical sprout inhibitors can be stored at 10°C (50°F) or higher without sprouting.

Field-Applied

Maleic hydrazide is a plant-growth regulator, applied in the field to control sprouting of potatoes in storage. It should be applied in a manner that ensures complete and uniform coverage. For example, apply Royal MH 60 SG at a rate of 5.65 kg in 300 L of water/ha (2.26 kg in 27 gal water/acre).

Timing is important. Recent research has shown that too early an application on some cultivars may result in phytotoxicity and reduced potato size. Consult manufacturer's recommendations for more detailed information on both rates and timing. Time of application may occur as early as 2–3 weeks past full bloom. Only apply to plants that are green and free from insects, disease and other damage.

Table 9–79.
Potato Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
APHIDS						
Soil application						
neonicotinoid (group 4)	imidacloprid	Admire 240 F	0.85–1.3 L[2]	0.34–0.52 L[2]	7	Will also provide control of leafhoppers and fleabeetles. 24-hr re-entry.
		Alias 240 EC	0.85–1.3 L[2]	0.34–0.52 L[2]		
	thiamethoxam	Actara 240 SC	378–488.9 mL[2]	151–195.5 mL[2]	90	Will also control leafhoppers. Maximum 1 application/yr.
Foliar applications						
pyridine	pymetrozine	Fulfill 50WG[3]	193 g	77.2 g	14	12-hr re-entry. Maximum 2 applications/yr.
neonicotinoid (group 4)	imidacloprid	Admire 240 F	200 mL	80 mL	7	Maximum 2 applications/yr for all uses. Do not make foliar application after a soil application in the same crop. 24-hr re-entry.
		Alias 240 EC	200 mL	80 mL	7	
	acetamiprid	Assail	56–86 g	22–34 g	7	Do not make more than 2 applications/yr. 12-hr re-entry.
	thiamethoxam	Actara 25 WG	105 g	42 g	7	Will also control leafhoppers. Do not use foliar Actara 25 WG on a field treated with Actara 240 SC in-furrow. Maximum 2 applications/yr. 12-hr re-entry interval.
organophosphate (group 1B)	dimethoate	Cygon 480	0.55–1.1 L	0.22–0.44 L	7	
		Lagon 480	0.55–1.1 L	0.22–0.44 L	7	
	methamidophos	Monitor 480	1.75–2.25 L	0.7–0.9 L	14	Also kills leafhoppers, tarnished plant bugs and flea beetles. It can be effective against Colorado potato beetle in areas where this insect has not developed resistance to this insecticide yet. 48-hr re-entry.
	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.44 kg	21	**Green peach and potato aphids only.** Maximum 4 applications/yr.
carbamate (group 1A)	pirimicarb	Pirimor 50 DF	425–550 g	178–220 g	3	
	oxamyl	Vydate L	2.3–3.0 L	0.92–1.2 L	7	**Green peach and potato aphids only.** 24-hr re-entry.
POTATO LEAFHOPPER, FLEA BEETLES, TARNISHED PLANT BUG						
pyrethroid (group 4)	cyhalothrin-lambda	Matador 120 EC	83 mL	33.2 mL	7	Also controls European corn borer. Maximum 3 ground applications or 2 aerial applications/yr. 24-hr re-entry.
	deltamethrin	Decis 5 EC	100–150 mL	40–60 mL	3	Maximum 3 applications/yr.
	permethrin	Pounce 384 EC	180–260 mL	72–104 mL	1	
	cypermethrin	Ripcord 400 EC	62.5–125 mL	25–50 mL	7	Use high rate on tarnished plant bug.
organophosphate (group 1B)	dimethoate	Lagon 480	0.55–1.1 L	0.22–0.44 L	7	Not for flea beetle.
		Cygon 480	0.55–1.1 L	0.22–0.44 L	7	
	naled	Dibrom	1.1 L	0.44 L	4	Not for tarnished plant bug.
	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.44 kg	21	Maximum 4 applications/yr.
	chlorpyrifos	Lorsban 4E	1.0 L	0.4 L	7	Not for leafhopper. 24-hr re-entry.
		Pyrinex 480 EC	1.0 L	0.4 L	7	
carbamate (group 1A)	oxamyl	Vydate L	2.3–3.0 L	0.92–1.2 L	7	24-hr re-entry.
	carbofuran	Furadan 480 F	0.55–1.1 L	0.22–0.44 L	7	48-hr re-entry. Maximum 2 applications/yr.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0–1.5 kg	0.4–0.6 kg	1	Use high rates for tarnished plant bug.
		Thiodan 4 EC	1.5–2.0 L	0.6–0.8 L	1	
		Thionex 50 WP	1.1–1.75 kg	0.44–0.7 kg	1	
LATE-SEASON CUTWORMS						
pyrethroid (group 4)	cypermethrin	Ripcord 400 EC	175 mL	70 mL	7	
organophosphate (group 1B)	chlorpyrifos	Lorsban 4 E	1.2–2.4 L	0.48–0.96 L	7	Apply in early evening for maximum control. 24-hr re-entry.
		Pyrinex 480 EC	1.2–2.4 L	0.48–0.96 L	7	

[1] PHI = Pre-Harvest Interval.

[2] Based on 90-cm (36-in.) row spacing.

[3] Fulfill 50WG causes cessation of aphid feeding shortly after application. However, aphids may remain on the plant for 2–4 days before they die.

Table 9–80.
Potato
Colorado Potato Beetle Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
Soil Treatments						
neonicotinoid (group 4)	imidacloprid	Admire 240 F	0.85–1.3 L[2]	0.34–0.52 L[2]		Use 7.5–12 mL per 100 m of row. For best results, spray directly on the seed piece.
	thiamethoxam	Actara 240 SC	378–488.9 mL[2]	151–195.5 mL[2]	90	Will also control leafhoppers. Maximum 1 application/yr.
Foliar Sprays						
biological (group 11)	*Bacillus thuringiensis*	Novodor	5.0–8.0 L	2–3.5 L	1	**For 1st and early 2nd instar Colorado beetle larvae only;** other stages and other insects not controlled. Field scouting is essential for timing the sprays.
neonicotinoid (group 4)	imidacloprid	Admire 240 F	200 mL	80 mL	7	Maximum 2 foliar applications/yr. DO NOT use foliar Admire on a field where even part (e.g., border rows) of the field has been treated with in-furrow Admire. 24-hr re-entry.
	acetamiprid	Assail 70 WP	40–80 g	16–32 g	7	Maximum 2 applications/yr. 12-hr re-entry.
	thiamethoxam	Actara 25 WG	105 g	42 g	7	Will also control leafhoppers. Do not use foliar Actara 25 WG on a field treated with Actara 240 SC in-furrow. Maximum 2 applications/yr. 12-hour re-entry interval.
naturalyte (group 5)	spinosad	Success 480 SC	166 mL	66.4 mL	7	Will also control European corn borer. Maximum 240 mL of product per year. 12-hr re-entry interval.
		Entrust 80W	50–100g	20–40 g	7	Will also control European corn borer (small larvae). Maximum 2 applications/yr. Maintain a spray pH of 6 or greater. 12-hr re-entry.
pyrethroid (group 4)	cyhalothrin-lambda	Matador 120 EC	83–125 mL	33.2–50 mL	7	Use the higher rate for larger instars and infestations. Maximum 3 applications/yr at the low rate or 2 applications/yr at the high rate. Do not exceed 250 mL/ ha (100 mL/acre)/yr. 24-hr re-entry interval.
	cypermethrin	Ripcord 400 EC	62.5–125 mL	25–50 mL	7	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 50 WP	1.0–1.5 kg	0.4–0.6 kg	1	
		Thiodan 4 EC	1.5–2.0 L	0.6–0.8 L	1	
		Thionex 50 WP	1.1–1.5 kg	0.44–0.6 kg	1	
carbamate (group 1A)	oxamyl	Vydate L	2.3–3.0 L	0.92–1.2 L	7	24-hr re-entry.
organophosphate (group 1B)	naled	Dibrom	1.1 L	0.44 L	4	
benzoylurea (group 15)	novaluron	Rimon 10 EC	410–820 mL	164–328 mL	14	Maximum 2 applications/yr. Apply at egg hatch to second instar. Also controls European corn borer (small larvae).

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[1] PHI = Pre-Harvest Interval.

[2] Based on 90-cm (36-in.) row spacing.

Once in storage, tubers treated with maleic hydrazide will not affect seed potatoes stored in the same storage. Crates formerly used for the storage of maleic hydrazide-treated tubers will not affect seed potatoes.

Storage-Applied

CIPC is also widely used for sprout inhibition. Apply it in storage as a dip, spray or aerosol just before sprouting starts. Potato tubers may be treated with this chemical before packaging for market. Do not apply CIPC at harvest time. Application as a gas to storage bins must be performed by a licensed applicator.

To use CIPC in packing lines, prepare 1 L of Sprout Nip EC in 35 L of water, stir to make an emulsion. Use 1 L of this emulsion per tonne of potatoes.

Do not use either of these treatments on potatoes grown for seed. Do not store seed potatoes in the same storage as CIPC-treated tubers or in crates that were in the storage when CIPC was applied.

Vine Killing

Vine killing is especially important to seed growers. An early kill controls tuber size and reduces the spread of virus diseases by aphids.

Chemical vine killers are not recommended for early potatoes. They limit the yield, size and dry-matter content without reducing skinning. However, where it is necessary to control size to reduce hollow heart, chemical vine killing may be of value for early potato crops.

Use Reglone (Diquat) as follows:

Heavy green top growth and weeds:	3.5 L/ha (1.4 L/acre)
Medium top growth or crop beginning to mature:	1.7–2.3 L/ha (0.68–0.92 L/acre)
Split application:	1.25–2.3 L/ha (0.5–0.92 L/acre) followed by 1.5 L/ha (0.6 L/acre) in 5–6 days

Apply in at least 550–1,100 L/ha (50–100 gal/acre) of clean water. Muddy water may inactivate Reglone. Allow 14–21 days after application until harvest to allow proper vine desiccation and tuber skin set.

Over-application or conditions that lead to very rapid kill may cause darkening at the stem end of the tuber.

Aircraft application of Reglone is not recommended. Ensure that no drift occurs from any of these materials to adjacent crops. The residue of these compounds on other crops may result in their seizure.

The product Ignite (glufosinate ammonium) is labelled as a dessicant on table stock and processing potatoes. Do not apply to potatoes grown for seed. Apply 3.0 L in 110–220 L water/ha (1.2 L in 10–20 gal water/acre). Use the higher rate of water when the crop canopy is dense. Apply to potato vines 14–21 days prior to harvest. Symptoms of dessication will appear within 2–4 days of applying Ignite.

The product "Des-I-Cate" (endothall) is also labelled. Apply to potato vines 10–14 days prior to harvest. Apply 17–22 L/ha (6.8–8.8 L/acre.) Use the high rate for medium to heavy vine growth and during cool (less than 21°C or 70°F) cloudy weather.

The use of roto-beaters is not recommended except where dead vines or weeds are a hindrance to the digger.

Storage

Store seed tubers separately from tablestock potatoes, in a disinfected storage area. Do not store seed potatoes in the same storage area as CIPC-treated tubers.

Healing of cuts and bruises is most rapid at a tuber temperature of 15°C–21°C (59°F–70°F). It is desirable to provide this temperature for 2–3 weeks at the beginning of the storage period. After this, the temperature should be lowered to 5°C (40°F) if potatoes are intended for tablestock or seed.

Potatoes intended for processing should be maintained at 10°C (50°F) and should never be subjected to temperatures below 5°C (40°F). It will be necessary to use a sprout inhibitor if potatoes are to be stored at 10°C (50°F) for an extended period.

The relative humidity in the storage should be as high as possible without causing condensation of moisture on tubers and the storage structure. However, if soft rot is prevalent or if the tubers are wet when first put into storage, the humidity should be kept down until the tubers dry. For more information, see the section *Cooling and Storage*, on page 47.

RADISHES

Production Requirements

Radishes are a cool-season crop. For best results, sandy loam soils with a pH of 6.5 are recommended. The ideal pH for muck soils is 5.1–5.5. Radishes are adversely affected by hot, dry weather and long days. Roots grown rapidly, with plenty of moisture, are mild, tender and attractive. Slow-growing roots become hot, tough and pithy. Long days (15 hr) and high temperatures result in misshapen roots, long tops and increased seed stalk production. Most radish varieties mature within 30–35 days.

Average Yields

Crop	per acre	per hectare
Radishes with tops	4–7 tons	9–16 tonnes

Cultivars

The most popular cultivars or strains have globe-shaped roots, red skins and leaves that are short-to-medium in length. Medium-top strains are preferable for early spring crops. Short-top strains are better adapted for growth during the longer-day period. Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding and Spacing

Radish seed may be sown as soon as the soil is workable. The minimum soil temperature required for seed germination is 4°C–7°C (40°F–45°F). Spring frosts or even snowfalls do not seriously injure the crop after the plants have emerged. Under favourable weather conditions, radish seedlings emerge 2 or 3 days after sowing. Sowing at regular intervals in the spring will provide a continuous harvest.

	Hand Harvest		Machine Harvest	
Row spacing	20–30 cm	8–12 in.	10–15 cm	4–6 in.
In-row spacing	2–2.5 cm	1 in.	2–2.5 cm	1 in.
Rate	11–17 kg/ha	10–15 lb/ac	22–34 kg/ha	20–30 lb/ac
Depth	1.5 cm	½ in.	1.5 cm	½ in.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

On mineral soils, apply up to 60 kg N/ha (53 lb/acre). On muck soils, apply 40 kg N/ha (36 lb/acre).

Phosphorus

Test the soil to determine phosphorus requirements. On mineral soils where the soil test values are 51 mg P per L soil (ppm) or higher, radishes are unlikely to respond to additional phosphate applications. For soils testing lower than 51 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

On muck soils, radishes are unlikely to respond to additional phosphate fertilizers if the soil test values are 61 mg P per L soil (ppm) or higher. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, radishes grown on both mineral and muck soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, and Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, apply and incorporate them prior to planting.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

Boron deficiencies on radish result in the splitting and cracking of the skin. Calcium deficiencies cause a backward cupping of leaves and discolouration of the leaf margins. Magnesium and manganese deficiencies appear as bronzing or yellowing of the leaf tissue between the veins.

Also see Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16. Use caution when applying boron. This nutrient can build to toxic levels quite quickly, harming rotational crops.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentra-

Table 9–81. Radish Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts Per Million (ppm)				
Most recently mature leaf	at harvest	3.0–4.5	0.25–0.4	1.5–3	1–2	0.3–0.5	–	30–50	20–40	30–50	15–30	3–10

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers,* 5th Edition. John Wiley & Sons, Inc. New York.

tions on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information, see the section *Plant Analysis*, on page 3.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–81, *Radish Nutrient Sufficiency Ranges*, above.

Integrated Pest Management

OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario,* contains a section on radish, illustrating many of the common diseases and insect pests.

Diseases

DAMPING-OFF AND ROOT ROTS

Use seed treated with thiram (dithiocarbamate group) seed protectant. Apply 90 g of Thiram 75 WP for every 25 kg of seed. Do not plant seed too deeply and avoid excessive irrigation.

See the section *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)*, on page 59, for more information.

DOWNY MILDEW

Identification: Symptoms appear as yellow spots on the upper leaf surfaces. Greyish-white fungi may be found on the underside of leaves. Downy mildew infections on the roots cause dark, discoloured areas extending from the crown, down the root. Infected roots may split or become invaded by secondary rot organisms.

Development: Infection can occur at any growth stage. Cool, moist conditions favour disease development. Downy mildew progresses rapidly at temperatures of 10°C–15°C (50°F–59°F). Prolonged periods of leaf wetness, caused by rain, heavy dews or fog, are also required.

Management Notes: Downy mildew fungi may survive for least 1 yr in the soil and 2 yr on infected seed. Plant into well-drained soils and follow a 2–3-year rotation with non-crucifer crops. Downy mildew–resistant cultivars are available. Avoid excessive use of overhead irrigation. See Table 9–82, *Radish Insect and Disease Control Recommendations*, on page 169.

FUSARIUM WILT (YELLOWS)

Identification: Infected seedlings rapidly turn yellow and then brown. Infections occurring later in the season cause severely weakened plants with spongy or hollow roots. The vascular tissue of infected roots becomes yellowish-brown.

Development: Maximum fusarium wilt growth occurs at soil temperatures of 27°C–29°C (81°F–84°F).

Management Notes: Fusarium wilt is both soil- and seed-borne. Use certified, treated seed and follow a 2–3-year crop rotation. Resistant cultivars are available. This disease is less common on high pH (alkaline) soils. Maintain a balanced soil pH.

BLACK ROOT

Identification: Infected seedlings die back. Late-season infections cause stunted plants and blackening on both the exterior and interior of the radish root. Black root infection usually begins as a dry rot. Secondary bacterial rots eventually cause the disintegration of the root.

Development: This soil-borne disease is favoured by moist, warm soil conditions. Infection occurs between 16°C–32°C (61°F–90°F), with maximum damage occurring at 27°C (81°F).

Management Notes: Plant into well-drained soils and follow a 4-year rotation with unrelated crops. Control all cruciferous weeds (wild mustard, yellow rocket, etc.). Resistant cultivars are available. Deep-plow infested residue.

SCAB

Identification: Pitted, corky, scale-like spots develop on infected roots. Lesions frequently have raised edges. They may enlarge to 1–2 cm ($^1/_4$–1 in.) in size.

Development: This soil-borne bacterial disease is favoured by dry soil conditions and high soil pH levels.

Table 9–82. Radish Insect and Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
ALTERNARIA, DOWNY MILDEW						
QoI (group 11)	pyraclostrobin	Cabrio EG	0.56–1.1 kg	224–440 g	3	Maximum 3 applications/yr. 72-hr re-entry (hand thinning).
RHIZOCTONIA – ROOT ROT, CROWN ROT, STEM CANKER						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/100 m row		15	One application/yr; applied in-furrow at planting or banded soon after emergence.
CABBAGE MAGGOT						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	85 mL/1,000 m of row		21	Drench with seed in 380 L (35 gal) water. 24-hr re-entry.
		Pyrinex 480 EC	85 mL/1,000 m of row		21	
FLEA BEETLES						
pyrethroid (group 3)	permethrin	Pounce 384 EC	180 mL	72 mL	2	
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5–1 L	7	
APHIDS						
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.44 kg	10	Control of aphids with these products has been inconsistent in many areas.
		Diazinon 500 E	1.1 L	0.44 L	10	
	malathion	Malathion 500 E	1.1–2.75 L	0.44–1.1 L	7	
CABBAGE LOOPER, IMPORTED CABBAGE WORM, DIAMONDBACK MOTH						
naturalyte (group 5)	spinosad	Success 480 SC	182 mL	73 mL	3	Maximum 3 applications/yr. Maintain a spray pH of 6 or higher.
		Entrust 80W	109 g	44 g	3	

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[1] PHI = Pre-Harvest Interval.

Management Notes: Do not grow radish in rotation with potato, carrot or beets. Rotations with grains are partially effective at reducing scab levels in the soil. Maintaining high soil moisture levels during root development may reduce infection.

OTHER DISEASES

Radishes may be infected by other diseases, such as clubroot, alternaria leaf spot, white rust and turnip mosaic virus (TuMV). For more information, see the section *Clubroot*, on page 86, and *Turnip Mosaic Virus (TuMV)*, on page 173.

Insects

APHIDS, CUTWORMS

For identification and management information on these common vegetable insects affecting radishes, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–82, *Radish Insect and Disease Control Recommendations*, above.

CABBAGE MAGGOT, CABBAGE LOOPER AND FLEA BEETLES

Several common brassica crop insect pests also attack radishes. Cabbage maggot larvae feed on radish roots, causing serious economic damage. Flea beetles feed on radish tops, rendering them unmarketable. Cabbage looper and other caterpillars are also occasional pests of radishes. For identification and management information, see the section *Insects*, on page 87, and Table 9–82, *Radish Insect and Disease Control Recommendations*, above.

Harvest and Storage

Radish quality is at its best May, June, September and October. Radishes remain in prime condition for only a few days and must be picked frequently. Bunched radishes are hand-harvested. Topped radishes may be harvested by hand or mechanically.

Remove the field heat from the crop immediately after harvest. Radishes can be stored for up to 3–4 weeks at 0°C (32°F) and a relative humidity of 95%–100%. For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

RHUBARB

Production Requirements

Rhubarb is a cool-season, perennial vegetable crop. It performs well in deep, well-drained soils. In the spring, growth resumes when soil temperatures reach 7°C (45°F). Temperatures above 26°C (80°F) cause leaf decline and seed stalk development during the months of July and August.

Rhubarb can be grown in the winter as a "forced" crop. Two-year-old crowns are moved inside for the winter. They require a dormancy period where temperatures are held below 5°C (40°F) for 7–9 weeks. Temperatures of 13°C–18°C (55°F–64°F) will initiate growth. Force rhubarb crowns in the dark, to prevent chlorophyll development. The use of gibberellic acid (Activol GA) is recommended to decrease the required dormancy period. Consult the label for details.

Average Yields

	per acre	per hectare
Fresh market & processing (15–20 stalks per crown)	12–15 tons	27–33 tonnes

Cultivars

Red stalks are preferred by most markets. While colour is often variety dependent, it is also affected by temperature. The red colour is more pronounced in stalks grown in relatively cool weather conditions. As the temperatures increase, the green colour predominates.

A list of rhubarb crown suppliers is available on the OMAFRA website at www.ontario.ca/crops. Paper copies are available by calling the Agricultural Information Contact Centre at 1-877-424-1300.

Planting and Spacing

Plant in rows 90–150 cm (36–60 in.) apart, with plants 60–120 (24–48 in.) apart in the row.

Plant crowns in a furrow 30–40 cm (12–15 in.) deep with the buds facing up. Cover the tip of each crown with at least 2.5–5 cm (1–2 in.) of soil.

> As crowns age, the bud development moves from the centre of the plant to the edges. If crowns are left undivided, the centre portion will become unproductive. Eventually it will rot and die, drastically reducing the overall productivity of the field. The best productivity occurs in the first 8–10 yr after planting.

Table 9–83. Rhubarb Nitrogen Recommendations

	Actual N	
Application Time	**kg/ha**	**lb/acre**
Field-Grown		
Preplanting	100	89
Annually		
Early spring	100	89
After harvest	100	89
Total	**200**	**178**
Crowns for Forcing		
Early spring	100	89
July[1]	180	160
Total	**280**	**249**

[1] As much as 100 kg N/ha (90 lb/acre) of the nitrogen recommendations may be applied through the fertigation system after harvest or in July.

Flower Stalk Removal

Flower stalk development reduces plant vigour and depletes valuable resources from the crown. Remove stalks while they are still small and before the flowers open. This can conveniently be done at the same time as harvesting in crops for processing. In crops grown for early fresh market or for forcing, a separate operation will be necessary.

Fertility

Nitrogen

See Table 9–83, *Rhubarb Nitrogen Recommendations*, above.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, rhubarb plants are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Band the phosphate below the crowns at planting.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, rhubarb plants are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Table 9–84.
Rhubarb
Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
APHIDS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	22.4–34.4 g	7	Maximum 5 applications/yr. 12-hr re-entry.
POTATO STEM BORER						
naturalyte (group 5)	spinosad	Entrust 80W	109 g	44 g	3	Maximum 3 applications/yr. Maintain a spray pH of 6 or higher.
		Success 480 SC	182 mL	72.8 mL	3	

[1] PHI = Pre-Harvest Interval.

Integrated Pest Management

Diseases

CROWN ROT AND VIRUS DISEASE

Crown rot infections cause sunken, brown lesions on the base of the stalks. Leaves wilt and die. Infected crowns are very susceptible to secondary bacterial soft rots. The fungi causing crown rot are common to many vegetable crops. Allow for at least 2–3 yr between growing vegetables and establishing rhubarb.

Virus diseases cause yellow mottling and spots on the leaves of infected plants. Plants become stunted.

Mark the plants with vigorous growth in June. Use these crowns as planting stock the following spring. Remove and discard all unhealthy crowns.

Insects

APHIDS

For information on identification and management, see the section *Aphids*, on page 60, and Table 9–84, *Rhubarb Insect Control Recommendations*, above.

POTATO STEM BORER

The potato stem borer is an occasional pest in Ontario. It overwinters as eggs on weedy grasses. The larvae hatch in mid-May. As they mature, the larvae move to larger-stalked plants such as corn, potatoes, tomatoes and rhubarb, attacking the stems and the crowns of affected plants. Larvae feed until mid-summer, at which time they pupate.

Control grassy weeds in and around rhubarb plantings. Chemical controls are only effective on small larvae, before they bore into the plant. See Table 9–84, *Rhubarb Insect Control Recommendations*, above.

RHUBARB CURCULIO

The rust-coloured rhubarb curculio feeds on stalks, crowns and roots. It overwinters on curl dock. Destroy dock weeds near the rhubarb planting.

Nematode Control

See the section *Nematodes*, on page 63.

Harvest and Storage

Much like asparagus, a limited harvest may occur in the second spring after planting. Remove leaf blades for marketing. Leaves contain oxalic acid and are poisonous to humans.

Store rhubarb at 0°C (32°F) for up to 2–4 weeks. Maintain a relative humidity (RH) of 95%. Stalks are very susceptible to dehydration.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

RUTABAGAS

Production Requirements

Rutabagas can be grown on a wide range of mineral soil types but will perform best on a deep, well-drained loam or sandy loam soil with a pH of 6.1–6.5, although a higher pH may be required for clubroot control. A frost-hardy crop, rutabagas experience their best growth during cool, fall weather conditions. Rutabagas require about 90 days from planting to harvest.

Average Yields

Crop	per acre	per hectare
Rutabagas	500–600 bu	1,250–1,500 bu

Cultivars

The recommended rutabaga cultivars are the Laurentian strains. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding and Spacing

The optimum soil temperature for germination is from 16°C–29°C (61°F–84°F). There is a very limited market for early rutabaga crops, seeded in April and May. Seed the main crop, grown for winter storage, from mid-June to early July. Rutabagas sown during this time can size up during the cool, fall weather, resulting in improved root quality.

	Metric	Imperial
Row spacing:	60–90 cm	24–36 in.
In-row spacing[1]:	13–15 cm	5–6 in.
Depth:	1.5 cm	0.5 in.
Rate:	approx. 500 g seed/ha	approx 7oz seed /acre

[1] Precision-seed or thin plants to the recommended in-row spacing.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

Apply up to 35 kg N/ha (31 lb/acre). If manure is used in the rotation, apply it at least 1 yr before the rutabaga crop is grown.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, rutabagas are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, rutabagas are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, apply and incorporate them prior to planting.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

BORON

Water-core or brown heart, caused by boron deficiency, first appears in young, growing roots as firm, brownish, water-soaked patches. Severely affected rutabagas may turn punky inside during storage.

Boron can be mixed with preplant fertilizer applications. Apply boron-enriched fertilizer as uniformly as possible. Foliar applications of Solubor are often as effective as larger amounts applied to the soil. Make the first foliar application when the roots are about 1.5–2.5 cm ($^2/_3$–1 in.) in diameter. The second and third applications may be applied at 10- to 14-day intervals. See Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Do not combine pesticides with boron sprays unless the label specifies compatibility. Use caution when applying boron. This nutrient can build to toxic levels quite quickly, harming rotational crops.

Integrated Pest Management

OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario*, provides a good summary of IPM for rutabagas in Ontario.

Diseases

DAMPING-OFF AND ROOT ROTS

Seed treated with thiram (dithiocarbamate group) will help prevent damping-off, seedling blight and seed decay. Use 90 g of Thiram 75 WP for every 25 kg of seed. See the section *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)*, on page 59, for more information.

BLACK ROT AND BLACK LEG

Identification: Seedlings infected with black rot usually die. Later infections cause stunted plants with yellow, wilting foliage. Leaf and stem veins and the vascular bundles under the skin of the root turn black. Root rots may also develop.

Seedlings infected with black leg may die or may simply lose their cotyledons. On mature plants, cankers develop on the root. Dry, sunken spots with dark borders develop in storage. Waxed roots rot rapidly.

Development: Rutabagas are susceptible to these diseases at the seedling stage, as mature plants and in storage.

Management Notes: Do not apply manure or compost containing rutabaga refuse or diseased rutabagas on land intended for rutabagas. Follow a 4–5-year rotation away from all cruciferous crops. The black leg pathogen can move with wind and water from adjacent fields. Control cruciferous weeds. Never store diseased rutabagas. Clean out and disinfect the storage area each spring. See the section *Storage Sanitation*, on page 50.

CLUBROOT

Identification: Galls develop on the taproot or secondary roots. Infected plants become stunted. Older leaves may turn yellow and drop. Younger leaves wilt during the heat of the day.

Development: The clubroot pathogen prefers temperatures of 19°C–23°C (67°F–73°F) and high soil moisture levels. This disease tends to be more severe on acid soils.

Management Notes: Clubroot is the most serious disease affecting rutabagas. Use a long crop rotation (at least 5 yr) with non-cruciferous crops to avoid infection. Avoid fields known to be infested. Maintain a soil pH of 7.2.

POWDERY MILDEW

Identification: White, powdery spots develop on the upper surface of older leaves. Leaves turn pale green to yellow and eventually die.

Development: Powdery mildew prefers periods of warm weather and low humidity. It requires some moisture (from heavy dews or intermittent rain) for initial infection.

Management Notes: The cultivar Laurentian is very susceptible to powdery mildew. Fungal spores are carried long distances by wind. Control must be initiated at the first appearance of symptoms. See Table 9–85, *Rutabaga Disease Control Recommendations*, on page 174.

TURNIP MOSAIC VIRUS (TUMV)

Identification: Older leaves turn yellow and drop prematurely. Leaves emerging after infection are stunted and wrinkled and show a yellow, mottled pattern. Roots become "goosenecked" and do not reach normal size.

Development: TuMV is spread by aphids. A rapid increase in infection usually begins in early July, when large numbers of winged aphids become active. Volunteer rutabagas and winter canola are the main overwintering sources of the virus.

Management Notes: Losses from turnip mosaic virus are especially heavy in plantings sown after mid-June. Applications of mineral oil (Superior 70 Oil) deter the feeding of virus-spreading aphids. See Table 9–85, *Rutabaga Disease Control Recommendations*, on page 174. Aphid control does not completely prevent the spread of the virus.

For more information see the sections, *Aphids*, on page 60, and *Viruses (General)*, on page 59.

For more information, see the OMAFRA Factsheets:

- *Turnip Mosaic Virus (TuMV) of Rutabaga*, Order No. 88-091.
- *Fungal Diseases of Cruciferous Crops*, Order No. 85-043
- *Black Rot of Cruciferous Crops*, Order No. 02-025

Table 9–85.
Rutabaga
Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
MOSAIC VIRUS						
N/A	mineral oil	Superior Oil 70	11 L in 550–1,100 L of water	4.4 L in 50–100 gal of water	21	Do not apply mineral oil in direct sunlight. Aphid feeding deterrent only.
POWDERY MILDEW						
QoI (group 11)	pyraclostrobin	Cabrio EG	560–840 g	224–336 g	3	3-day re-entry (hand thinning). Maximum 3 applications/yr. Do not use more than 2 applications before rotating to a different fungicide group.
DMI (group 3)	propiconazole	Topas 250 E	400 mL in minimum 200 L of water	160 mL in minimum 18 gal of water	21	A second application may be made 20 days after the first.
		Mission 418 EC	240 mL in minimum 200 L of water	96 mL in minimum 18 gal of water	21	Make 2 applications/yr with the 1st application at 50 days after planting and the 2nd application 20 days later.
inorganic (group M1)	sulphur	Microscopic Sulphur	6.8 kg in 675–1,125 L of water	2.75 kg in 60–100 gal of water	0	Maximum 5 applications/yr. This product is not compatible with Superior Oil.
RHIZOCTONIA						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 ml/100 m row in 50–100 L water		40	One application/yr; applied in-furrow at planting or banded soon after emergence.

[1] PHI = Pre-Harvest Interval.

Insects

CUTWORMS, APHIDS

For identification and management information on these common vegetable insects affecting rutabagas, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–86, *Rutabaga Insect Control Recommendations*, on page 175.

CABBAGE MAGGOT

Identification: The white, legless maggots feed and burrow in the roots, rendering them unmarketable.

Period of Activity: Cabbage maggots overwinter as pupae in the soil. There are three periods of maggot damage related to the emergence of the three generations of flies. The first generation is the most active and most damaging. It occurs from mid-May through June (flowering of yellow rocket). A second occurs in mid-July (flowering of day lilies) and a third in late August (flowering of goldenrod). These dates are only approximate, and activity varies, depending on regional temperatures and differences in soil type.

Thresholds: Monitoring programs for cabbage maggot adults may help with spray timing. A Growing Degree Day (GDD) model has been developed for cabbage maggot. Using a base of 6°C, first generation adults are expected between 314 and 398 GDD. Second generation adults are expected between 847 and 960 GDD. Third generation adults are expected between 1,446 and 1,604 GDD.

Management Notes: Follow a 3–4-year crop rotation. Do not grow early and late rutabagas in the same field or near winter canola, early broccoli, cabbage or cauliflower. Control of root maggots can be timed to coincide with the egg-laying activity of each generation of adults. See Table 9–86, *Rutabaga Insect Control Recommendations*, on page 175.

FLEA BEETLES

Identification: Small, shiny, black beetles feed on leaves and cotyledons, leaving a "shot-hole" appearance. They may also feed on the stem below the soil surface. Larvae feed on the roots.

Table 9–86.
Rutabaga
Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
CABBAGE ROOT MAGGOT						
Treatment at Planting						
organophosphate (group 1B)	chlorpyrifos	Lorsban 15 G	0.6–1 kg/ 1,000 m of row	0.18–0.3 kg/ 1,000 ft of row	30	24-hr re-entry.
Treatment After Planting						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	210 mL/ 1,000 m of row (in 125 L of water)	64 mL/ 1,000 ft of row (in 11 gal of water)	28	Apply on soil, 10 cm (4 in.) on each side of the plant, 10, 28, 49 and 70 days after seeding. Maximum 4 applications/yr. 24-hr re-entry.
FLEA BEETLES						
pyrethroid (group 3)	cypermethrin	Ripcord 400 EC	123 mL	49 mL	21	
	permethrin	Pounce 384 EC	180 mL	72 mL		Apply before 8-leaf stage.
carbamate (group 1A)	carbaryl	Sevin XLR	1.25–2.5 L	0.5- 1.0 L	7	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2.0 L	0.8 L	45	Also control aphids. Maximum 2 applications/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	45	
LEAF-EATING CATERPILLARS						
naturalyte (group 5)	spinosad	Success 480 SC	182 mL	73 mL	3	Maximum 3 applications/yr. Maintain a spray pH of 6 or higher. 72-hr re-entry (hand thinning).
		Entrust 80 W	109 g	44 g	3	
chlorinated cyclodiene (group 1A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	45	Maximum 2 applications/yr.
		Thionex 50 WP	2 L	0.8 L	45	
CUTWORMS						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–1.0 L	30	May be used at the rate of 2.4 L/ha (1.0 L/ acre) as a preplanting treatment. Apply once at seedling stage (2–5 leaves), when damage first appears. 24-hr re-entry.
		Pyrinex 480 EC	1.2–2.4 L in 200–400 L water	0.5–1.0 L in 20–40 gal water	30	

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[1] Pre-Harvest Interval.

Period of Activity: Rutabagas plants are most vulnerable at the seedling stage. Larval feeding on the root may reduce marketability.

Thresholds: None established.

Management Notes: Target controls at the adult beetle stage. There is no control for larvae established in roots. Insecticide should be applied as soon as the beetles appear in the field. Beetles may migrate into the field over several weeks, resulting in the need for multiple applications. If insecticide drenches are used to control root maggots, flea beetles may also be controlled.

See Table 9–86, *Rutabaga Insect Control Recommendations*, above. To limit the development of resistance, alternate between insecticide groups.

LEAF-EATING CATERPILLARS

Cabbageworm, diamondback moth and cabbage loopers may attack rutabagas. For more information, see the section *Imported Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar*, on page 90. Also see Table 9–86, *Rutabaga Insect Control Recommendations*, above.

Before feeding rutabaga tops or trimmings to livestock, check all pesticide labels for restrictions.

Nematode Control

See the section *Nematodes*, on page 63, for control recommendations.

Harvest and Storage

Damaged and bruised rutabagas are likely to rot and do not store well. To reduce losses from post-harvest diseases, change the water in the wash tank frequently or add fresh water continuously to keep water as clean as possible. Rinse with clean water and dry immediately. Trimming after washing also helps reduce storage rots. Use calcium hypochlorite (bleach) in the rinse water to reduce losses after waxing. See the section *Storage Sanitation*, on page 50.

Waxing

Rutabagas are normally hot-waxed just before being marketed. Waxing improves their appearance, keeps them clean, protects freshly trimmed surfaces from disease organisms and prevents undue moisture loss and shrinkage during the marketing period. Waxing is not recommended for rutabagas being held in storage.

Immerse clean, dry rutabagas for one second in a "rutabaga/turnip" wax at 126°C (259°F) and then pack as desired for market. Temperatures must be kept low after waxing. Waxed rutabagas can spoil within a few days at room temperature. Rutabaga wax is available from International Group Incorporated (IGI), 50 Salome Dr., Agincourt, Ontario, Tel. 416-293-4151. Ask for "turnip wax" — product code 2291.

Storage

Disease-free rutabagas will keep up to 6 months. Store at 0°C (32°F) and a relative humidity of 90%–95%. Maintain adequate ventilation and air movement throughout the storage area. Clean the storage area thoroughly between crops. See Table 6–5, *Proven Disinfectants*, on page 50.

For more information see Chapter 6, *Food Safety and Storage*, on page 45.

For more information, see the OMAFRA Factsheet, *Storing Rutabagas*, Order No. 80-001.

SPECIALTY VEGETABLES

Many of the specialty vegetables grown in Ontario are of Asian and Middle Eastern origin. These crops belong to a range of plant families that includes legumes, brassica crops and cucurbits. Pest management strategies developed for more traditional crops may be helpful in these crops, since they often have a similar insect and disease complex.

Nomenclature

Many of the crops of Asian origin have different names in different languages (Mandarin Chinese, Cantonese Chinese, Vietnamese, Korean or Japanese, for example). Table 9–87, *Specialty Vegetables*, on page 178, summarizes some of the Asian specialty vegetable crops grown in Ontario.

For more information, see the OMAFRA Factsheet, *Asian Vegetables Grown in Ontario*, Order No. 98-033.

Fertility

Because of the wide range of specialty crops, a single fertility recommendation cannot be made. However, a balanced fertility program based on a soil test can form the basis for good crop health. Experience from traditional, related crops will also be useful. See Chapter 1, *Vegetable Crop Fertility*, on page 1, for more information on nitrogen, phosphorus, potassium and the micronutrients.

Integrated Pest Management

OMAFRA Publication 701, *Integrated Pest Management for Crucifers in Ontario*, provides a comprehensive reference for many of the insects and diseases affecting specialty vegetables.

Diseases

Many of the diseases affecting specialty crops are seedborne. If possible, purchase certified, hot-water treated seed.

The following best management practices can help reduce disease problems:

- use treated seed
- deep-plow crop residues into the soil
- eliminate cull piles
- follow a 3–4-yr rotation with unrelated crops
- remove weed hosts
- reduce overhead irrigation
- use only healthy transplants grown in clean plug trays and sanitized greenhouses

COMMON DISEASES OF SPECIALTY VEGETABLES

Asian radish (lo bok, daikon, moo): Turnip mosaic virus, downy mildew, alternaria leaf blight

Nappa cabbage (siew choy, da bai cai, baechu): Turnip mosaic virus, downy mildew, soft rot, alternaria leaf spot, clubroot, pseudocercosporella leaf spot

Bok choy, gai choy, yow choy, pak choy, gai lan, etc.: Turnip mosaic virus, downy mildew, soft rot, clubroot, pseudocercosporella leaf spot, alternaria leaf blight

Cucurbits (fuzzy squash, bitter melon, winter melon): Powdery mildew, downy mildew, mosaic viruses, bacterial wilt, angular leaf spot, scab, anthracnose

For identification, management and chemical control options for insects and diseases of brassica specialty vegetables, see the section *Integrated Pest Management*, on page 84.

Harvest and Storage

Most specialty vegetables reach maturity in 40–70 days (sometimes 90–100 days for late fall nappa cabbage) under good growing conditions. All specialty vegetables are hand-harvested. Most radish and melon types are washed before marketing. The leafy greens are packed directly into crates or boxes in the field.

Leafy greens are a very perishable product. If they are cooled immediately after harvest and topped with ice, they can be stored for up to 10–14 days. Optimal storage conditions are 0°C (32°F) and a relative humidity of 95%–100%.

For more information see Chapter 6, *Food Safety and Storage*, on page 45.

The following OMAFRA Factsheets contain more information on pest management:

- *Insects, Disease and Disorders of Asian Vegetables*, Order No. 00-095
- *Leafminers Attacking Field Vegetables and Greenhouse Crops*, Order No. 00-039
- *Turnip Mosaic Virus (TuMV) of Rutabaga*, Order No. 88-091
- *The Swede Midge – A New Pest In Crucifer Crops in Ontario*, Order No. 03-035

Table 9–87. Specialty Vegetables

English	Chinese[1]	Korean	Japanese	Vietnamese	Latin
Edible amaranth (callaloo, calalbo, tampala)	hinn choy (C), xian cai (M)	chambirum	hi yu na	rau den do	*Amaranth mangostanus* *A. gangeticus*
Asian water celery or Water dropwort	shui qin (M)	minari	seri	cang nuoc, rau can nuoc	*Oenanthe stolonifera*
Asparagus bean or Snake bean	dau guak (C), cai dow (M)	gin kong	sasage	dua-dua	*Vigna unguiculato* var. *sesquipedalis*
Bitter melon	ku gua (M), fu gua (C)	ssunoi	ni ga uri	muop dang, khoqua	*Momordica charantia*
Bitter melon leaves	fu gua yip			la khoquo	*Momordica charantia*
Burdock root	ngao pong (C)	uang	gobo		*Arctium lappa*
Chinese broccoli or Chinese kale	gai lan (C), jie lan (M)		kailaan	cai ro	*Brassica alboglabra*
Nappa cabbage or Chinese cabbage	siew choy (C), won bok (C), da bai cai (M), huan ya bai (M)	baechu	hakusai	cai bac thao, cai dai	*Brassica rapa* var. *pekinensis group*
Chinese chives	gow choy (C), jiu cai (M)	buchu	nira	he	*Allium tuberosum*
Chinese cucumber	wong gua (C), huang gua (M)	oi		dua leo	*Cucumis sativus* var. *sativus*
Big leaf mustard	dai gai choy (C), da jie cai (M)	gat	karashina	cai zanh	*Brassica juncea* var. *involutus;* var. *foliosa*
Chinese okra or Sponge gourd	guang dong si gua, si gua		shokuyou hechima, hechima	muop khia, muop huong	*Luffa acutangula,* *Luffa aegypitaca*
Chinese squash/pumpkin	nam gua (C), nan gua (M)	ho bak	kabocha	bi ro	*Cucurbita moschata*
Japanese pumpkin	yin du nan gua		seiyou-kabocha	bi	*Cucurbita maxima*
Chrysanthemum greens	tong hao cai (M), tong ho choy (C)	ssukgat	shungiku	tan o, cai cui	*Chrysanthemum coronarium*
Flowering edible rape	yow choy (C), you cai (M)	yuchaeip	aburana	cai ngot	*Brassica rapa* var. *oleifera*
Fuzzy squash	mao gua, jie gua (M), tsit gua (C)	ho bak	tohgan	bi chanh	*Benincasa hispida* var. *chieh-qua*
Edible mallow (melokhia)				rau day	*Corchorus olitorius*
Red/green mustards	gai choy (C), jie cai (M)	gat	karashina	cai xanh	*Brassica juncea* var. *rugosa;* var. *crispifolia*
Malabar spinach	lo kwai (C), san choy (C), zi luo kui (M), lu luo (M)		tsuru-murasaki	mong to'i	*Basella alba,* *Basella rubra*
Flowering Chinese leaf cabbage	choy sum (C), cai xin (M)		saishin	cai ngot non	*Brassica rapa* var. *parachinensis*
Flat flowering Chinese leaf cabbage	nai yow choy (C)				*Brassica rapa* var. *narinosa*
Rosette Chinese leaf cabbage	tak choy (C), wu ta cai (M)		tatsoi	cai tua xai	*Brassica rapa* var. *rosularis*
Purple mint, beefsteak plant	zi su (C)	dulketip	shiso	tia to	*Perilla frutescens,* *Perilla crispa*
Asian radish	lo bok (C), luo bu (M)	moo	daikon	cu-cai	*Raphanus sativum* *Longipinnatus* group
Potherb mustard	shui cai (C)		kyona, mizuna		*Brassica juncea* var. *japonica*
Salad rocket (arugula)					*Eruca vesicaria*
Snow peas	ho lan dow	wando	saya endo		*Pisum sativum* var. *macrocarpon*
Snow pea shoots	dow miu (C), dou miao (M)	wandusun	tohbyo		*Pisum sativum* var. *macrocarpon*
Thick petiole white Chinese leaf cabbage	bai cai (M), bok choy (C)	bok choy	shakushina	cai thuong hai	*Brassica rapa* var. *chinensis*
Thin petiole white Chinese leaf cabbage	pak choy (C), xiao bai cai (M)	pak choy	shakushina, chingensai (green stem)	cai trang laon	*Brassica campestris rapa* var. *chinensis*
Water spinach	tung choy (C), kongxin cai (M)	kongshim-chae	kankon, asagaona, ensai	rau muong	*Ipomoea aquatica*
Winter melon	tung kwa (C), don gua (M)		tohgan	bao	*Benincasa hispida*

[1] C = Cantonese Chinese, M = Mandarin Chinese

SPINACH & SWISS CHARD

Production Requirements

Spinach production occurs mainly in the spring or fall. Under long days and warm-weather conditions, plants quickly bolt (produce flower stalks) and become unmarketable. Bolting susceptibility may also be variety specific. Sandy or sandy-loam soils are preferred for the early and over-wintered crops. Highest yields are often obtained on muck soils. The ideal pH range for spinach on mineral soils is 6.5–7.5. On muck soils, the target pH is 5.1–5.5.

Most spinach varieties reach maturity in 40–50 days under good growing conditions. Early spring plantings may require 50–70 days.

Average Yields

Crop	per acre	per hectare
Processing spinach	10,000–12,000 lb	11,000–13,000 kg
Fresh-market spinach (24 bunches per carton)	400 cartons	1,000 cartons

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229.

Seeding and Spacing

Sow outside as soon as the soil can be worked, in early spring through to early May. Plant from July 31 to August 31 for a fall crop. Do not sow seed in mid-summer, as bolting may occur. For over-wintered spinach, sow from September 1–10.

Seed will germinate readily at soil temperatures as low as 3°C–4°C (37°F–39°F.) Optimum germination occurs at 10°C–16°C (50°F–61°F). At higher temperatures, there is a more rapid emergence but decreased percentage germination.

	Spinach		Swiss Chard	
Row spacing:	30 cm	12 in.	30 cm	12 in.
In-row spacing:	5–10 cm	2–4 in.	10–12 cm	4–5 in.
Rate:	12 kg/ha	11 lb/acre	12 kg/ha	11 lb/acre

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.

Table 9–88.
Spinach Nitrogen Recommendations

Soil Type	Actual N	
	kg/ha	lb/acre
Mineral Soils		
Preplant	55	49
Side-dress	55	49
Total	**110**	**98**
Muck Soils		
Preplant[1]	75	67

[1] On muck soils, if rainfall has been excessive, an additional 55 kg/ha (50 lb/acre) may be side-dressed.

Broadcast and incorporate the recommended preplant nitrogen with all the required phosphate and potash. For early sown crops, apply the total nitrogen recommendation as a preplant application. See Table 9–88, *Spinach Nitrogen Recommendations*, above.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, spinach plants grown on both muck and mineral soils are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12, or Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, spinach plants grown on both muck and mineral soils are unlikely to respond to additional potash applications. For soils testing lower than 181 mg K per L soil (ppm), see Table 1–11, *Phosphorus and Potassium Requirements: Vegetables on Muck Soils*, on page 13, and Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

If phosphate and potash are required, apply and incorporate them prior to planting.

Table 9–89.
Spinach Nutrient Sufficiency Ranges

		N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
Plant Part	**Time of Sampling**	**Percent (%)**						**Parts Per Million (ppm)**				
Most recently mature leaf	30 days after seeding	3–4.5	0.3–0.5	3–4	0.6–1	1–1.6	–	–	50–100	50–70	20–40	5–7
	harvest	3–4	0.25–0.5	2.5–3.5	0.6–1	1–1.6	–	–	30–50	50–70	20–40	5–7

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers.* 5th Edition. John Wiley & Sons, Inc. New York.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients,* on page 17.

BORON

Boron deficiencies on spinach and swiss chard are not common but may occur during periods of hot, dry weather. Leaves become twisted with light spots developing on the petioles. Internal breakdown may occur in the roots. External cankers may also develop on the root surface.

See the section *Boron,* on page 18, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients,* on page 16. Use caution when applying boron. This nutrient can build to toxic levels quite quickly, harming rotational crops.

MAGNESIUM

A magnesium deficiency may occur on spinach. The usual symptoms are yellowing of older leaves, while the veins remain dark green. See the section *Magnesium* and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients,* on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information, see the section *Plant Analysis,* on page 3.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–89, *Spinach Nutrient Sufficiency Ranges,* above.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

For identification and management information, see the section *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium),* on page 59. Also see Table 9–90, *Spinach Seed Treatments,* below.

DOWNY MILDEW

Identification: Infection usually begins on the mature, lower leaves and spreads inward. Chlorotic (yellowish) or pale-green areas appear on the upper surface of the leaves. Greyish-purple mould spores develop on the underside of the leaf.

Development: Infection can occur at any growth stage. Cool temperatures of 10°C–15°C (50°F–59°F) and prolonged periods of leaf wetness, dew or fog support development. Downy mildew fungi survive for at least one year in the soil and two years in infected seed.

Management Notes: Resistant cultivars are available. Follow a three-year rotation with non-host crops and plant into well-drained soils. Fall spinach crops should not be grown in, or adjacent to, fields where an infected spring crop was grown. See Table 9–91, *Spinach and Swiss Chard Disease and Insect Control Recommendations,* on page 181.

Table 9–90.
Spinach Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL-LS	metalaxyl-M	20–40 mL per 100 kg seed	damping-off	Not for greenhouse-grown spinach.
Thiram 75 WP	thiram	90 g per 25 kg seed	seed decay and damping-off	

Table 9–91.
Spinach and Swiss Chard
Disease and Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
DOWNY MILDEW						
QoI (group 11)	azoxystrobin	Quadris Flowable	1.125 L	450 mL	7	**Spinach only.** Begin applications prior to disease development.
LEAFMINERS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	86 g	34.4 g	7	Maximum 5 applications/yr. Alternate applications with different insecticide groups. 12-hr re-entry.
chitin biosynthesis inhibitor (group 17)	cyromazine	Citation 75 WP	188 g in 200 L water	75 g in 18 gal water	7	Maximum 5 applications/yr. 12-hr re-entry.
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.44 kg	10	**Spinach only.**
		Diazinon 500 E	1.1 L	0.44 L	10	
	malathion	Malathion 25 W	5.5–7.0 kg	2.2–2.8 kg	7	
APHIDS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	22.4–34.4 g	7	Maximum 5 applications/yr. Alternate applications with different insecticide groups. 12-hr re-entry.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	Spinach only. Maximum 1 application/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1 kg	0.44 kg	10	**Spinach.** Control of aphids with diazinon has been inconsistent in many areas.
		Diazinon 500 E	1.1 L	0.44 L	10	
		Diazinon 50 W	1.1 kg	0.44 kg	14	**Swiss chard.** Control of aphids with diazinon has been inconsistent in many areas.
		Diazinon 500 E	1.1 L	0.44 L	14	
	dimethoate	Cygon 480	700 mL	280 mL	7	**Swiss chard only.** Maximum 2 applications/yr.
		Lagon 480	700 mL	280 mL	7	
	naled	Dibrom	1.1–1.65 L	0.44–0.66 L	4	Control of aphids with naled has been inconsistent in many areas.
carbamate (group 1A)	pirimicarb	Pirimor 50 DF	500 g	200 g	7	**Spinach only.** 24-hr re-entry. Maximum 3 applications/ yr.
CABBAGE LOOPER, BEET WEBWORM						
biological (group 11)	*Bacillus thuringiensis*	Thuricide HPC	2.0–4.25 L	0.8–1.7 L	0	**Spinach only. Looper only.**
		Dipel 2XDF	275–550 g	110–220 g	0	
naturalyte (group 5)	spinosad	Success 480 SC	182 mL	73 mL	1	Maximum 3 applications/yr. Maintain a spray pH of 6 or higher.
		Entrust 80 W	109 g	44 g	1	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	2 L	0.8 L	14	**Spinach only. Looper only.** Maximum 1 application/yr.
		Thionex 50 WP	1.75 kg	0.7 kg	14	
organophosphate (group 1B)	naled	Dibrom	1.1–1.65 L	0.44–0.66 L	4	**Spinach only. Looper only.**

[1] PHI = Pre-Harvest Interval.

FUSARIUM WILT

Identification: Fusarium wilt causes the outer leaves to wilt and turn yellow. Severe infections may progress to younger leaves. Light brown-to-black lesions develop on the roots, and the water-conducting vessels turn black.

Development: Moist soil conditions are required for initial root infection. Once established, the disease will progress quickly, especially if the soil becomes dry and the plants become stressed. Fusarium wilt is most severe at soil temperatures of 27°C (81°F).

Management Notes: In soils where this is a problem, do not seed spinach from May 31 to August 15. Some genetic tolerance may exist. Maintain a high soil pH; alkaline soils do not favour disease development.

SPINACH BLIGHT, CUCUMBER MOSAIC VIRUS, BEET MOSAIC VIRUS

Identification: Infected plants become stunted with progressive yellowing and mottling. Beet mosaic virus produces small spotting early in the infection period without the distortion of the leaves common to other viruses.

Development: Cucumber mosaic virus is usually transmitted by aphids. Infestations are often associated with high temperatures and high aphid activity.

Management Notes: Virus-resistant cultivars are available. Control weeds in adjacent fencerows. Milkweed, ground cherry, pokeweed, chickweed and mother-wort are alternative hosts to the cucumber mosaic virus. Avoid growing spinach near other mosaic-susceptible vegetable crops. See the section *Viruses (General)*, on page 59.

Insects

APHIDS

For identification and management information on this common pest of many vegetable crops, see the section *Aphids*, on page 60, and Table 9–91, *Spinach and Swiss Chard Disease and Insect Control Recommendations*, on page 181.

LEAFMINERS

The pea leafminer adult causes severe stipling (bronzing) damage to leaves of spinach and swiss chard. Mining of the leaves by pea leafminer larvae is not as common. For more information, see the section *Leafminers*, on page 81. Other species of leafminer create twisted mines underneath the leaf surface. See Table 9–91, *Spinach and Swiss Chard Disease and Insect Control Recommendations*, on page 181.

CABBAGE LOOPER

Cabbage looper can cause sporadic damage in Ontario. Five percent infestation is suggested as a threshold. For more information, see the section *Imported Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar*, on page 90. See also Table 9–91, *Spinach and Swiss Chard Disease and Insect Control Recommendations*, on page 181.

BEET WEBWORM

This is a rare problem in Ontario spinach and Swiss chard crops. However, it can cause sporadic damage. Dark-coloured webworm larvae produce webs on the leaves and petioles. See Table 9–91, *Spinach and Swiss Chard Disease and Insect Control Recommendations*, on page 181.

For more information on spinach and Swiss chard IPM, consult the following OMAFRA Factsheets:

- *Leafminers Attacking Field Vegetables and Greenhouse Crops*, Order No. 00-039
- *Caterpillar Pests of Crucifer Crops*, Order No. 99-035
- *Aphids Infesting Lettuce and Celery in Ontario*, Order No. 00-053

Nematode Control

To avoid damage from sugarbeet cyst nematode, do not plant spinach following rhubarb, beets or spinach. (See the section *Nematodes*, on page 63.)

Harvest and Storage

Spinach can be harvested when it has five or six leaves. Higher yields result when plants have 10–12 leaves. Most of the Ontario crop is machine harvested. Spinach is usually washed before marketing.

Remove the field heat from spinach as soon as possible after harvest. Stored product may last for 10–14 days under good conditions. Store at 0°C (32°F) and a relative humidity of 95%–100%.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

SUGARBEETS

Production Requirements

Sugarbeets can be grown on a wide range of soil types. It is important to have good surface and subsurface drainage. Sugarbeets will perform best at a pH of 6.5–7.2. Manganese deficiency may become a problem at pH levels above 7.2.

Plant sugarbeets as early as possible for maximum yield potential. Planting can begin in late March if soil and weather conditions are suitable. Early harvest starts in late September, while main harvest runs from mid-October into November, once temperatures are suitable for building storage piles.

Average Yields

Crop	per acre	per hectare
Sugarbeets with sugar levels of 17%–19%	21–25 tons	47–55 tonnes

Cultivars

Follow processor's requirements.

Soil pH

Soil pH can have a significant impact on the breakdown of several commonly used field crop herbicides.

Carryover of these herbicides will severely injure sugarbeets. It takes time after the application of lime for the pH to fully adjust. Allow for sufficient time for herbicide breakdown after the pH adjustment. Even where the average pH of a field is suitable, areas of low or high pH may still exist.

imazethapyr (Pursuit, Clean Sweep, Conquest, Valor)	degrades very slowly at pH less than 6.0–6.5.
flumetsulam (Broadstrike Dual Magnum) **cloransulam (First Rate)**	breaks down very slowly below a pH of 6, increased activity above a pH of 7.8.
chlorimuron-ethyl (Classic)	degradation stops at a pH greater than 7.

Seeding and Spacing

The minimum germination temperature for sugarbeets is 4.5°C (40°F). Plant enough seed to give an emerged stand of 150–180 sugarbeets per 30 m (100 ft) of row. Adjust the seeding rate according to the row width. Aim for the high end of the range in 71–76-cm (28–30-in.) rows and the lower end of the range for 56-cm (22-in.) rows.

Table 9–92. Sugarbeet In-Row Spacing

Expected % Emergence[1]	Seed spacing needed to achieve:			
	180 sugarbeets		150 sugarbeets	
	per 30 m (100 ft) of row			
	cm	in.	cm	in.
40	6.8	2.7	8.1	3.2
50	8.4	3.3	10.2	4.0
60	10.2	4.0	12.2	4.8
70	11.9	4.7	14.2	5.6
80	13.5	5.3	16.3	6.4

[1] Normal emergence is approximately 60% in our growing areas. Aim for a minimum emergence of 180 sugarbeets/30 m (100 ft) in 71–76 cm (28–30 in.) rows and 150 sugarbeets/30 m (100 ft) in 51–56 cm (20–22 in.) rows.

See Table 9–92, *Sugarbeet In-Row Spacing*, above. These spacings will consistently produce more recoverable sugar per hectare than lower stands. The use of coated and primed seed improves plant emergence.

Proper planter set-up and maintenance are extremely important for successful establishment of the sugarbeet stand. Good seedbed preparation is also important for achieving early seeding dates, rapid seedling emergence and a uniformly spaced stand. Deep or excessive spring tillage reduces soil moisture and increases crusting, impacting sugarbeet emergence. Planting depth will vary with soil types and moisture conditions. A depth of 2.5 cm (1 in.) is generally satisfactory.

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

After field corn, use 120–150 kg N/ha (107–134 lb/acre). Reduce nitrogen application to 100–130 kg (89–116 lb/acre) when following other crops. Excess nitrogen will not increase sugarbeet yield, but will decrease sugar content and clear juice purity.

Table 9–93.
Sugarbeet
Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Apron XL LS	metalaxyl	20–40 mL per 100 kg seed	pythium damping-off	For use in commercial seed-treatment applicators only.
Apron FL	metalaxyl	93 mL per 100 kg seed	pythium seed rot, seedling blight	
Allegiance FL	metalaxyl	93 mL per 100 kg seed	pythium seed rot, seedling blight	
Thiram 75 WP	thiram	90 g per 25 kg seed	seed decay, seedling blight, damping-off	Do not feed treated clippings to livestock.

Phosphorus

Soil tests are required to determine phosphorus requirements. Where the soil test values are 51 mg P per L soil (ppm) or higher, sugarbeets are unlikely to respond to additional phosphate applications. For soils testing lower than 51 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Potassium

Soil tests are required to determine potassium requirements. Where the soil test values are 151 mg K per L soil (ppm) or higher, sugarbeets are unlikely to respond to additional potash applications. For soils testing lower than 151 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Excessive application of potassium will lead to luxury consumption by the sugarbeet plant. This has a negative effect on clear juice purity and sugar recovery.

Starter Fertilizer

Fields with high soil-test levels of phosphorus and potassium do not generally require starter fertilizer. Where starter is required, place it in a band at least 5 cm (2 in.) to the side and 5 cm (2 in.) below the seed to avoid seedling injury.

Manganese

Manganese deficiencies are more common on heavier textured soils with high pH and high soil organic matter levels. Deficient plants show marked yellowing between the leaf veins; the veins themselves remain green. If soybeans regularly exhibit manganese deficiencies in the field, then manganese deficiency may also occur in sugarbeets. To correct a deficiency, spray with manganese sulfate. See the section *Manganese*, on page 19, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Integrated Pest Management

Diseases

DAMPING-OFF AND ROOT ROTS

Varieties recommended by the processor have considerable tolerance to seedling diseases and damping-off. See Table 9–93, *Sugarbeet Seed Treatments*, above, and the section *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)*, on page 59.

CERCOSPORA LEAF SPOT

Identification: Numerous small, circular lesions develop on the leaves. Small black dots in the centre of the lesions can be seen with a hand lens. Cercospora leaf spot can lead to defoliation and reductions in both yield and sugar content.

Development: Cercospora leaf spot is most active from mid-July through early September. Air temperatures above 24°C (75°F) with extended periods of leaf wetness due to rain, heavy dews, or fog are favourable for disease development.

Thresholds: Use BEETcast to determine optimum fungicide timing. See the section *BEETcast*, on page 185. If BEETcast is unavailable, begin preventative spray programs as soon as leaf symptoms appear.

Management Notes: Approved sugarbeet varieties have varying levels of leaf spot tolerance.

Manage the currently registered cercospora fungicides very carefully to avoid the development of fungicide resistance. Start the fungicide spray program with a systemic product such as Headline. Follow BEETcast to time this and subsequent applications correctly.

Switch to another systemic fungicide group for the second application. Further applications, if required, can again include a systemic fungicide. **Avoid making sequential**

applications of Headline EC or Senator 70 WP. If possible, incorporate a dithiocarbamate-type fungicide (e.g., Dithane, Penncozeb, Manzate, Polyram) into the program. Follow a shorter DSV spray interval when using the dithocarbamate products.

See Table 9–94, *Sugarbeet Disease and Insect Control Recommendations*, on page 186.

Fungicide applications can cease once daily maximum temperatures drop below 15°C (59°F).

BEETcast

The BEETcast program uses temperature and leaf wetness measurements to schedule preventative fungicide applications, before the damaging disease symptoms are visible. BEETcast calculates a daily Disease Severity Value (DSV) for each location. A zero means conditions were not favourable for disease development, due to cool temperatures or dry leaves. Favourable conditions, due to warm temperatures and periods of leaf wetness, are given a rating of 1 to 4. Spray applications are made when the accumulated daily DSVs reach a target number.

BEETcast DSVs are available from Weather Innovations Incorporated, with support from the Ontario Sugarbeet Growers' Association. For more information, contact Weather Innovations Incorporated at 519-352-5334 or visit their website at www.weatherinnovations.com.

RHIZOCTONIA CROWN ROT

Identification: Rhizoctonia initially attacks the base of the plant, causing wilting and the eventual death of the foliage. It progresses to rotting of the crown and root.

Development: Rhizoctonia crown rot is a warm weather disease. It becomes active late in the season, at temperatures of 25°C–33°C (77°F–91°F). Fields considered at high risk for *Rhizoctonia* infections include those with a history of the disease or fields in which a host crop was grown the previous year. Stressful growing conditions will also make plants more susceptible to infections.

Management Notes: Avoid throwing soil onto sugarbeet crowns during cultivation. Rotate with corn or small grains. Rhizoctonia-resistant varieties are available. Do not dump sugarbeet tare dirt onto fields scheduled for sugarbeets the following year. Fungicides must be applied early in the season to be effective. See Table 9–94, *Sugarbeet Disease and Insect Control Recommendations*, on page 186.

POWDERY MILDEW

This pathogen does not overwinter in our growing area and must be blown in from western North America. It is not generally of economic concern, but sporadically some fields can become heavily infected.

Insects

CUTWORMS, WIREWORMS

For identification and management information on these common vegetable insects affecting sugarbeets, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–94, *Sugarbeet Disease and Insect Control Recommendations*, on page 186.

FLEA BEETLES AND SPRINGTAILS

Identification: Flea beetles are tiny, dark-coloured beetles. They eat small, round holes in the leaves. Springtails are small insects that cause scraping or scarring on leaves and roots. They are sometimes confused with flea beetles.

Period of Activity: Early in the season.

Thresholds: These pests do not usually cause economic injury in Ontario. Flea beetle control may be necessary if 25% or more of seedlings show damage.

Management Notes: See Table 9–94, *Sugarbeet Disease and Insect Control Recommendations*, on page 186.

ROOT APHIDS

Root aphids are a localized but serious pest in some years. Look for woolly spots, waxy exudate or the presence of aphids on roots. Certain approved sugarbeet varieties have tolerance to this pest.

LEAFMINERS, LEAFHOPPERS, SPIDER MITES

These pests are often present in Ontario sugarbeet fields. However, they do not usually cause economic damage. If populations build to damaging levels, see Table 9–94, *Sugarbeet Disease and Insect Control Recommendations*, on page 186.

Lamb's-quarters is an alternate host for leafminers. Good weed control can reduce infestations.

Table 9–94.
Sugarbeet
Disease and Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
CERCOSPORA LEAFSPOT						
benzimidazole (group 1)	thiophanate-methyl	Senator 70WP	420–560 g	170–227 g	21	Systemic. Always rotate with a different fungicide group. Follow an IPM and resistance management strategy. Maximum 1 application/yr. Do not feed any part of treated plants to livestock.
QoI (group 11)	pyraclostrobin	Headline EC	670–900 mL	271–364 mL	7	Systemic. Use high rate when disease pressure is high. Maximum 4 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 48-hr re-entry.
dithiocarbamate (group M2)	mancozeb	Manzate Pro-Stick	2.25 kg	0.9 kg	21	Apply every 7–10 days. 24-hr re-entry. Do not use treated beet tops for feed.
		Penncozeb 80 WP	2.25 kg	0.9 kg	21	
	metiram	Polyram DF	2.25 kg	0.9 kg	21	Do not use treated beet tops for feed.
inorganic (group M1)	copper hydroxide	Parasol WP	2.25–4.5 kg	0.9–1.8 kg	1	Apply at 10–14-day intervals once disease is detected. Add suitable non-herbicidal agricultural oil at 5.5 L/ha.
RHIZOCTONIA ROOT AND CROWN ROT						
QoI (group 11)	azoxystrobin	Quadris Flowable	4–6 mL/100 m of row	1.2–1.8 mL/100 ft of row	100	In-furrow application. Make only 1application/yr.
			0.5–1.1 L	0.2–0.45 L	100	Banded over the row before the 6th leaf stage. Do not apply over the row if Quadris has previously been applied in-furrow.
POWDERY MILDEW						
QoI (group 11)	pyraclostrobin	Headline EC	670–900 mL	271–364 mL	7	Use high rate when disease pressure is high. Maximum 4 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 48-hr re-entry.
WIREWORM						
organophosphate (group 1B)	terbufos	Counter 15 G	45 g/100 m of row	13.7 g/100 ft of row	120–150	Apply at planting. Do not place in direct contact with seed. Rates based on minimum 50 cm (20 in.) spacing. 48-hr re-entry.
CUTWORMS						
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.5–1.0 L	90	24-hr re-entry.
FLEA BEETLES, LEAFHOPPERS, SPIDER MITE						
organophosphate (group 1B)	malathion	Malathion 500 E	1.1 L	0.45 L	0	Flea beetles. Apply at the 3–5-leaf stage when insects or damage first appears. 24-hr re-entry.
	naled	Dibrom	2.2 L	0.9 L	5	Red spider mites, leafhoppers.

[1] PHI = Pre-harvest Interval.

Note: As the Ontario sugarbeet crop is processed entirely in the U.S., all products used must have both Canadian and U.S. registrations on sugarbeets. Your processor may have specific restrictions and recommendations. Check with your processing company representative before spraying.

Sugarbeet Cyst Nematode

Rotation to non-host crops for 4–5 yr will significantly reduce populations of this nematode. Avoid rotation with other host crops, including table beets, cruciferous crops and rhubarb. Varieties with tolerance to SBCN are available. SBCN is an expanding problem in Michigan but has not been confirmed in the Ontario growing area since the 1960s. (See the section *Nematodes*, on page 63.)

Harvest and Storage

Handle sugarbeets as gently as possible to minimize breakage and bruising. Adjust flails or knives to remove all green leaf material from the crowns. Damaged and poorly topped beets cause storage problems in the piles. Top only what you can be sure of harvesting the same day. Topped beets will freeze in the field much more quickly than beets with tops.

Frosted or frozen sugarbeets deteriorate rapidly in the pile. When sugarbeet crowns are frosted or frozen in the field, delay harvest until the tissue has had a chance to thaw and stabilize.

SWEET CORN

Production Requirements

Sweet corn is well adapted to a wide range of growing areas. Sweet corn is sensitive to cold soils and to frost. It performs best under warm growing conditions. Early-season production is well suited to sandy-loam soils. Later plantings benefit from the higher moisture-holding capacity of silt-loam and clay-loam soils. The target pH is 5.6–6.

Sweet corn maturity ranges from 60–100 days, depending on the variety. Fresh-market sweet corn is usually picked 21 days after 50% silk. Processing fields are harvested slightly later.

Average Yields

Crop	per acre	per hectare
Processing	6–8 tons	13–18 tonnes
Fresh market	1,000 doz (200 bags)	2,500 doz (500 bags)

Cultivars

Growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229. Processing sweet corn growers must grow varieties specified by the processor.

Seeding and Spacing

Plant populations of 16,000–18,000 plants/acre (40,000-45,000 plants/ha) are commonly used for early fresh-market varieties. Main season and processing densities range from 18,000–22,000 plants/acre (45,000–55,000 plants/ha).

Row spacing:	75–90 cm	30–36 in.
In-row spacing:	20–25 cm	8–10 in.
Rate:	11–17 kg seed/ha	10–15 lb/acre
Depth: **(Always plant into moisture.)**	4–7.5 cm	1.5–3 in.

Soil Temperature

The minimum soil temperature needed for germination depends on the cultivar and its gene type. Crops planted into cold soils suffer from delayed, uneven emergence. Cold soils also increase the risk of losses to early-season pests, such as 3-leaf dieback, seedcorn maggots and wireworms.

Gene Type	Minimum Soil Temperature
Normal (su)	13°C (55°F)
Sugar-enhanced (se)	16°C (61°F)
Supersweet (sh_2)	18°C (64°F)

Isolation

All sweet corn must be isolated from field corn. Supersweet (sh_2) varieties must be separated from both normal (su) and sugar enhanced (se) varieties. Cross pollination will turn sh_2 kernels starchy. If se varieties are pollinated with su pollen, they will revert back to normal sugar levels.

Yellow is the dominant colour gene. Isolation of white varieties is necessary to avoid colour contamination. Bicolour cobs pollinated with yellow pollen will have a lower proportion of white kernels. Isolate indian corn from all types of sweet corn. It will cause black kernels to appear in the cobs.

Separate incompatible varieties by at least 100 m (350 ft) or schedule the plantings so that pollen-shed is at least 2–3 weeks apart.

For more information, see the OMAFRA Factsheet, *High Sugar Sweet Corn*, Order No. 90-126

Fertility

Nitrogen

If manure is applied or legume sod is plowed down, reduce the nitrogen (N) application. (See Table 1–8, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 9, and Table 1–9, *Adjustment of Nitrogen Requirement Where Sod Containing Legumes Is Plowed Down*, on page 10.)

On all soils, 90 kg N/ha (80 lb/acre) is recommended.

A portion of the nitrogen should be applied preplant or at the time of planting. Apply the planter-fertilizer in a band 5 cm (2 in.) to the side and 5 cm (2 in.) below the seed. To avoid fertilizer injury, do not exceed the maximum banded application rates listed below. Side-dress the remainder of the nitrogen before the corn is 30 cm (12 in.) high.

	Maximum Banded Application Rates[1]	
Fertilizer	**kg/ha**	**lb/acre**
Nitrogen	75	67
Nitrogen + potash	75 + 45	67 + 40
Urea	40	36
Urea + potash	40 + 40	36 + 36

[1] Based on 75-cm (30-in.) rows

Table 9–95.
Sweet Corn Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts Per Million (ppm)				
Whole seedlings	3-leaf stage	3–4	0.35–0.5	2.5–4	0.6–0.8	0.25–0.5	0.4–0.6	50–100	40–100	30–40	10–30	5–10
	6-leaf stage	3–4	0.25–0.5	2.5–4	0.5–0.8	0.25–0.5	0.4–0.6					
Most recently mature leaf	30 in. tall	2.5–4	0.2–0.4	2.5–4	0.5–0.8	0.20–0.4	0.2–0.4	40–100	40–100	25–40	10–30	4–10
	Just prior to tassle	2.5–4	0.2–0.4	2–3.5	0.3–0.6	0.15–0.4	0.2–0.4	30–100	30–100	20–40	10–20	4–10
Ear leaf	Tasselling	1.5–2.5	0.2–0.4	1.2–2	0.3–0.6	0.15–0.4	0.2–0.4	30–100	20–100	20–40	10–20	4–10

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*. 5th edition. John Wiley & Sons, Inc. New York.

Alternatively, pop-up fertilizer may be applied in the furrow directly with the seed:

- Do not use more than 9 kg nitrogen-plus-potash/ha (8 lb/acre).
- Do not place urea with the seed.

Avoid "pop-up" starter fertilizers that use urea as the nitrogen source. If the N component is more than half as much as the P component, the starter may contain urea.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 31 mg P per L soil (ppm) or higher, sweet corn fields are unlikely to respond to additional phosphate applications. For soils testing lower than 31 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

Phosphate is best applied in a band at the time of planting. Depending on the soil test rating, additional broadcast P applications may or may not be necessary.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 121 mg K per L soil (ppm) or higher, sweet corn fields are unlikely to respond to additional potash applications. For soils testing lower than 121 mg K per L soil (ppm), see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15.

Micronutrients

Crops vary greatly in their response to micronutrient fertilizers. For complete information, see the section *Micronutrients*, on page 17.

ZINC

Zinc deficiencies occasionally occur on coarse sandy-loam soils with low organic matter. Plants develop pale yellow bands between the leaf veins, particularly near the leaf axils of the new growth. Soil tests are useful for identifying potential deficiencies. Where zinc is required, it may be applied to the soil mixed in the fertilizer or as a banded application. See the section *Zinc*, on page 20, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information, see the section *Plant Analysis*, on page 3.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–95, *Sweet Corn Nutrient Sufficiency Ranges*, above.

Integrated Pest Management

Diseases

THREE-LEAF DIEBACK

Symptoms occur either before or shortly after emergence. The young shoot and roots suddenly die off, resulting in poor stand establishment. Two fungi are responsible: *Penicillium* occurs as a contaminant on the seed, whereas *Pythium* is common in most soils. Seeds planted into cool, wet soils and sh2 varieties are most susceptible.

To prevent three-leaf dieback, use one of the fungicide seed treatments listed in Table 9–96, *Sweet Corn Seed Treatments*, on page 190.

Table 9–96.
Sweet Corn
Seed Treatments

Trade Name	Active Ingredients	Rate	Pests Controlled	Notes
Insecticide and Fungicide Combinations				
DCT	diazinon/captan/ thiothanate-methyl	125 g per 25 kg seed	seed maggots, seedling blights, including *Penicillium* spp.	Seed box treatment.
Agrox B-2	diazinon/captan	85 g per 25 kg seed	seed and root maggots, damping-off and seedling blights	Seed box treatment Use within 1 month of treatment. Do not use on seed previously treated with an insecticide.
Agrox CD	diazinon/captan	50 g per 25 kg seed	seed and root maggots, wireworms, damping-off and seedling blights	Seed box treatment Use on seed previously treated with captan or thiram. Do not use on seed previously treated with an insecticide.
Cruiser 5FS + Maxim 480 FS + Apron XL LS	thiamethoxam + fludioxonil +metalaxyl-M	83–166 mL +5.2–10 mL + 20–40 mL per 100 kg seed	wireworm, seedcorn maggot, white grubs and flea beetles, pythium, penicillium and fusarium damping-off and root rots	For use in commercial seed-treatment plants only. Do not graze or feed to livestock within 45 days of planting.
Cruiser 5 FS + Dynasty 100 FS	thiamethoxam + azoxystrobin	83–166 mL + 10 mL per 100 kg seed	wireworm, seedcorn maggot, white grubs and flea beetles, broad spectrum seed decay and damping-off.	For use in commercial seed-treatment plants only. Do not graze of feed to livestock within 4 weeks of planting.
Fungicide Only				
Dividend XL RTA	difenoconazole/ metalaxyl-M	325 mL per 100 kg seed	penicillium, pythium and rhizoctonia seedling blights	Do not graze or feed to livestock within 60 days of planting.
Apron FL	metalaxyl	46–110 mL per 100 kg seed	pythium seed rot and seedling blight	For use in commercial seed-treatment applicators only. Do not feed crop to livestock for 4 weeks after planting.
Allegiance FL	metalaxyl	46–110 mL per 100 kg seed	pythium seed rot and seedling blight	
Apron XL LS + Maxim 480 FS	metalaxyl-M + fludioxonil	20–40 mL +5.2–10 mL per 100 kg seed	pythium, penicillium and fusarium damping-off and seedling blights	**For use in commercial seed-treatment plants only.**
Dynasty 100FS + Maxim XL	azoxystrobin + fludioxonil	10 mL + 11–22 mL per 100 kg seed	broad spectrum seed decay and damping-off	**For use in commercial seed-treatment plants only.** Do not graze or feed to livestock within 4 weeks of planting.
Captan FL	captan	60–85 mL per 25 kg seed	seed decay, damping-off and seedling blights	
Thiram 75 WP	thiram	55 g per 25 kg seed	seed decay and damping-off	Do not feed treated clippings to livestock.
Insecticide Only				
Gaucho 480 FL	imidacloprid	140–520 mL per 100 kg seed	flea beetles and wireworms	**For use in commercial seed-treatment plants only.** Use high rate for flea beetles. Carry-over of Gaucho-treated seed is not recommended.
Poncho 600	clothianidin	see label for rates	wireworm, seedcorn maggot, corn root worm, white grubs, flea beetles	**For use in commercial seed-treatment plants only.** One-year plant-back restrictions for leafy, root and tuber vegetables.
Cruiser 5FS	thiamethoxam	83–166 mL per 100 kg seed	wireworm, seedcorn maggot, white grubs and flea beetles	**For use in commercial seed-treatment plants only.** Use high rate for wireworm. Do not graze or feed to livestock within 45 days of planting.

Seed treatments usually provide only 2 weeks of protection to the seed. Planting into suitably warm soils and ensuring rapid germination is the best protection against three-leaf dieback. For more information, see the section *Damping-Off and Root Rots (Pythium, Phytophthora, Rhizoctonia, Fusarium, Penicillium)*, on page 59.

STEWART'S WILT

Identification: Plants infected before the 5-leaf stage become stunted, wilt and die. Later infections cause pale green or yellow stripes, running parallel to the leaf veins. Late damage is easily confused with magnesium deficiency. Wilt-infected plants exhibit brown, mushy tissue inside the stem.

Development: Stewart's wilt is transmitted by the corn flea beetle. Yield losses are most significant when susceptible varieties are infected before the 7-leaf stage. On susceptible varieties, losses at this stage may range from 40%–100%.

Management Notes: Mild winters favour flea beetle survival and increase the risk of problems the following season. There is no control for this disease, however, many varieties have excellent resistance to the Stewart's wilt bacteria. Corn flea beetle control may help prevent the spread of the Stewart's wilt bacterium. See the section *Corn Flea Beetle*, below, for more information.

RUST

Identification: Reddish-brown (rusty) pustules develop on the upper leaf surface. The size of each lesion ranges from 1–3 mm. Older pustules turn blackish-brown.

Development: Rust infection requires cool weather (16°C–23°C or 61°F–73°F) and 3–6 hours of leaf wetness. Heavy overnight dews favour development. The rust fungi does not overwinter in Ontario. Epidemics arise from spores blown in from the U.S. and Mexico.

Thresholds: Prior to silking, plants with more than 6 pustules per leaf will benefit from a fungicide application.

Management Notes: There is a wide range of rust resistance in sweet corn cultivars. Rust infections occurring after silk emergence are unlikely to result in yield losses. See Table 9–97, *Sweet Corn Disease and Insect Control Recommendations*, on page 192.

Insects

SEEDCORN MAGGOTS, WIREWORMS, CUTWORMS, APHIDS, SLUGS

For identification and management information on these common vegetable insects affecting sweetcorn, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, Table 9–96, *Sweet Corn Seed Treatments*, on page 190, and Table 9–97, *Sweet Corn Disease and Insect Control Recommendations*, on page 192.

CORN FLEA BEETLE

Identification: These small (2-mm), black beetles cause elongated scratches on the leaves and transmit the Stewart's wilt virus. Beetle feeding itself does not cause yield losses.

Period of Activity: Beetles overwinter in the top 5 cm (2 in.) of the soil/residue. They emerge when soil temperatures reach 18°C (64°F.) The first peak of activity is in late June. Mild winters favour beetle survival and increase the risk of Stewart's wilt transmission.

Thresholds: Susceptible varieties may require foliar control if more than 10% of the plants have severe feeding injury or there are more than 2 beetles per plant.

Management Notes: Insecticide seed treatments and varietal tolerance provide the best flea beetle control. Susceptibilty to Stewart's wilt varies greatly between varieties. Many early hybrids are particularly vulnerable. See Table 9–96, *Sweet Corn Seed Treatments*, on page 190.

Foliar insecticides applied for cutworm control may also reduce adult flea beetle populations.

EUROPEAN CORN BORER

Identification: Full-grown corn borer larvae are 2.5 cm (1 in.) in length. They are a greasy white colour, with a dark head and spots on each segment. Eggs are shiny, white and laid in clusters of 30 that resemble fish scales. Corn borer larvae feed briefly on the leaves but soon tunnel into the protection of the stalk. As the crop matures, borers move from the stalk into the ear.

Period of Activity: Borers overwinter as pupae in corn stubble. Southwestern Ontario experiences two generations per year. Usually, the first-generation adults emerge in mid-June, and the population peaks in mid-July. Second-generation populations peak in August.

In the rest of the province, single-generation corn borers usually emerge in late June or early July. Populations peak in late July to early August. Many areas within Southwestern Ontario (Lambton, Middlesex, Oxford, Brant, Norfolk and Niagara) have an overlap of corn borer generations. These areas experience a sustained peak flight for much of July and August.

Sweet corn is susceptible to corn borer from the late-whorl stage (12–14 leaves) until harvest.

Thresholds: 5% feeding injury or the presence of eggs warrants an insecticide application.

Management Notes: Begin monitoring at the mid-whorl stage. If monitoring indicates a need, apply the first spray at tassel emergence. Direct the sprays down into the whorl and at the developing ears. For good corn borer control, all sprays must target the small larvae. Second-generation larvae often move quickly towards the ear.

Table 9–97.
Sweet Corn
Disease and Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
RUST						
DMI (group 3)	propiconazole	Tilt 250 E	500 mL in 200 L water	200 mL in 18 gal water	14	Aerial application permitted. Under severe disease pressure, make second application in 14 days. May be tank-mixed with Matador or Ripcord insecticides.
		Bumper 418 EC	300 mL in 200 L water	120 mL in 18 gal water	14	
QoI (group 11)	pyraclostrobin	Headline EC	400–600 mL	160–240 mL	7	48-hr re-entry. Maximum 2 applications/yr.
	azoxystrobin	Quadris Flowable	453 mL in min. 200 L water	181 mL in min. 20 gal water	7	Maximum 2 applications/yr.
chloronitrile (group M5)	chlorothalonil	Bravo 500	3.2 L	1.3 L	14	Maximum 2 applications/yr.
APHIDS						
carbamate (group 1A)	pirimicarb	Pirimor 50 DF	550 g	220 g	3	Ground application. Minimum 450 L of water/ha (40 gal/acre). Aerial application. Minimum 20–45 L of water/ha (2–4 gal/acre). Maximum 1 application/yr.
CORN ROOTWORM						
pyrethroid (group 3)	tefluthrin	Force 3.0 G	37.5 g per 100 m of row	11.5 g per 100 ft of row		Apply in-furrow at planting.
carbamate (group 1A)	carbofuran	Furadan 480 F	500 mL	200 mL	7	**Rootworm adults only.** 48-hr re-entry.
CUTWORMS[2]						
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	83 mL	33.2 mL	–	24-hr re-entry. Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application.
	cypermethrin	Ripcord 400 EC	175 mL	70 mL	21	Apply to moist soils up to 5-leaf stage. Do not disturb soil for 5 days after application.
	permethrin	Pounce 384 EC	180–390 mL	72–156 mL	–	
organophosphate (group 1B)	chlorpyrifos	Lorsban 4E	1.2–2.4 L	0.48–0.96 L	70	Apply during 2–5 leaf stage in 200–400 L water/ ha (18–36 gal/acre). 24-hr re-entry.
		Pyrinex 480 EC	1.2–2.4 L	0.48–0.96 L	70	
SLUGS						
inorganic	ferric phosphate	Sluggo	25–50 kg	10–20 kg	0	Use high rates on severe infestations.

[1] PHI = Pre-Harvest Interval.

[2] Cutworm treatments are most effective if applied in the early evening or at night when cutworms are most active.

Maintain good spray coverage of the leaves, tassles and ears. There is a very low tolerance for insect damage in the fresh-market industry. Applications at 5–7-day intervals usually give satisfactory control. See Table 9–98, *European Corn Borer, Corn Earworm and Fall Armyworm Control Recommendations*, on page 193.

CORN EARWORM

Identification: Earworm larvae range in colour from yellowish, to green or brown, with a fine double stripe running down their backs. The larvae are slightly larger than the European corn borer. Female earworm moths lay their eggs on corn silk. The larvae are usually found in the top third of the ear.

Period of Activity: Corn earworm do not overwinter in Ontario. They arrive from the U.S. and Mexico on tradewinds. In Southwestern Ontario, adult moths usually appear in mid-to-late July, or earlier, depending on the season. In eastern and northern areas, arrival occurs in mid-to-late August. In cooler years, these areas may not experience corn earworm at all.

Table 9–98.
European Corn Borer, Corn Earworm and Fall Armyworm Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
pyrethroid[2] (group 3)	cyhalothrin-lambda	Matador 120 EC	83 mL	33.2 mL	1	Maximum 3 ground applications or 2 aerial applications/yr. 24-hr re-entry.
	deltamethrin	Decis 5 EC	250–300 mL	100–120 mL	5	Maximum 2 ground or 1 aerial applications/yr. Not registered for fall armyworm.
	cypermethrin	Ripcord 400 EC	175 mL	70 mL	5	
	permethrin	Pounce 384 EC	275–375 mL	110–150 mL	1	Maximum 2 aerial applications permitted. Use 180 mL/ha (72 mL/acre) for fall armyworm.
biological (group 11)	*Bacillus thuringiensis*	Dipel 2X DF	0.56–1.12 kg	0.22–0.44 kg		**European corn borer only.** Apply when pinhole feeding is observed on 5% of plants. Maximum 6 applications/yr.
		Bioprotec CAF	2.8–4.0 L	1.1–1.6 L		
carbamate (group 1A)	carbofuran[3]	Furadan 480 F	1.1 L	0.44 L	7	**European corn borer only.** Maximum 2 applications/yr. 48-hr re-entry.[3]
	carbaryl	Sevin XLR	2.5–4.0 L	1–1.6 L	1	**European corn borer only.**
	methomyl	Lannate TNG	430–625 g	172–250 g	3	24-hr re-entry. Use high rate for corn borer. Not registered for fall armyworm.
organophosphate (group 1B)	acephate	Orthene 75 SP	0.75–1.1 kg	0.3–0.44 kg	21	**European corn borer only.** Maximum 4 applications/yr.
naturalyte (group 5)	spinosad	Success 480 SC	83 mL	33.2 mL	7	**European corn borer only.** Use only on very small larvae and low populations. Maximum 2 applications/yr. Maintain a spray pH of 6 or greater.
		Entrust 80 W	50 g	20 g	7	

[1] PHI = Pre-Harvest Interval.

[2] Pyrethroid sprays rapidly degrade at temperatures over 26.5˚C (80˚F), and more frequent spray applications are often required. Spraying during cooler evening temperatures may increase the performance of these products.

[3] If prolonged, direct contact with corn foliage will occur, do not re-enter treated fields between 2–14 days of application without wearing appropriate protective clothing such as long pants and a long-sleeved shirt.

Earworm activity is highest in hot weather conditions. Peak flights often occur immediately after severe thunderstorms.

Thresholds: Use pheromone traps to monitor corn earworm populations. Insecticide applications are based on the number of moths caught per week and the average temperatures. See Table 9–99, *Corn Earworm Spray Intervals*, below.

Table 9–99.
Corn
Earworm Spray Intervals

Moths/trap per week	Spray Intervals	
	<27˚C (81˚F)[1]	27˚C (81˚F)[1]
1–6	5–7 days	5–7 days
7–90	5 days	4 days
More than 90	4 days	3 days

[1] Daily maximum temperature.

Management Notes: Sweet corn is only susceptible to corn earworm damage while the silks are green. Good spray coverage of the rapidly growing silks is important. Pyrethroid sprays break down quickly under high temperature conditions, and more frequent spray applications are required. See Table 9–98, *European Corn Borer, Corn Earworm and Fall Armyworm Control Recommendations*, above.

Transgenic varieties (Bt Sweet Corn) have complete resistance to corn borers and partial resistance to earworms and fall armyworms. Insecticides may be needed for other pests if pressure is high. Check with your seed company representative for availability and planting restrictions.

Bee Warning

Bees often visit sweet and field corn to collect water and pollen. Spraying may cause bee poisoning. Many of the insecticides used to control sweet corn pests are highly toxic to bees.

Damage to bees is reduced when sprays are applied in the late evening when bees are not foraging. Do not treat when the wind is blowing. Avoid spray drift to roadsides and adjacent fields where plants might be in bloom.

Advise local beekeepers of spraying activity (see the section *Prevent Bee Poisoning*, on page 53).

FALL ARMYWORM

Fall armyworm are also migratory pests. They usually arrive in Ontario slightly later than the corn earworm. The pale-green or tan-coloured larvae create large, rough holes in the leaves and the cob. The spray threshold is 5% feeding injury. Sprays used for corn borer and corn earworm usually control the armyworm as well. See Table 9–98, *European Corn Borer, Corn Earworm and Fall Armyworm Control Recommendations*, on page 193.

CORN ROOTWORM

Corn rootworm adults lay their eggs in the fall in corn fields. The following spring, emerging larvae will feed on corn roots. They weaken the root system, often causing lodging (or goosenecking). Crop rotation will almost always control corn rootworm populations; however, a new variant of the corn rootworm is present in Ontario. This variant lays its eggs in soybean crops. Additional control may be necessary if this variant is present in fields rotated solely with soybeans. See Table 9–96, *Sweet Corn Seed Treatments*, on page 190, and Table 9–97, *Sweet Corn Disease and Insect Control Recommendations*, on page 192.

Adult beetles occasionally feed on corn silks in late July–early August. Populations are usually kept under control by corn borer and earworm sprays. Severe feeding may result in poor kernel set.

GRUBS

White grubs and European chaffer are an occasional pest of sweet corn, especially on coarse, sandy-loam soils. They feed on the roots of emerging seedlings, causing them to wilt and die. When pulled, affected plants will be root-less. White grubs have a 3-year life cycle and are most commonly associated with turf and berry crops. The European chaffer is an annual grub. Its peak feeding activity is May through mid-June. See Table 9–96, *Sweet Corn Seed Treatments*, on page 190.

For more information on integrated pest management in sweet corn, see the following OMAFRA Factsheets and publication:

- *European Corn Borer in Sweet Corn and Other Horticultural Crops*, Order No. 97-019
- *Corn Earworm*, Order No. 95-065
- *Managing Cutworms in Vegetable Crops*, Order No. 00-055
- *Managing Wireworm in Vegetable Crops*, Order No. 00-047
- Publication 12, *Sweet Corn Production Manual*

Birds

RED-WINGED BLACKBIRDS AND CROWS

Noisemakers, such as propane cannons and digital distress calls, are often used to scare birds away from sweet corn crops. For full effectiveness, start using these devices before the corn becomes attractive for feeding and move them around frequently. Avoid planting near marshy and wooded areas. Cultivars with ears well-covered by husks are somewhat resistant to bird damage. For complete bird control information, see the section *Birds*, on page 64.

Harvest and Storage

Sweet corn is harvested while the kernels are at the early milk stage. Eating quality declines quickly if cobs are left in the field past this stage. Under good storage conditions, supersweet varieties may last for up to 1 week. Normal (su) and sugar-enhanced (se) varieties lose quality after 2–3 days.

Remove the field heat from the crop as quickly as possible after harvest. Store at temperatures close to 0°C (32°F) with a relative humidity of 95%–98%.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

SWEET POTATOES

Production Requirements

The sweet potato is a warm-season vegetable that requires sandy to sandy-loam soils low in organic matter. Sweet potatoes are ideally suited to 3,000 or more crop heat units and take 100–130 days to mature, depending on variety. Transplants (slips) should be planted in late May or early June, once the danger of frost is past. Avoid planting sweet potato after sod or in fields with a history of perennial weed or grass pressure.

Average Yield

Crop	per acre	per hectare
sweet potatoes	8,000–12,000 lb tablestock product	9,000–13,500 kg tablestock product

Cultivars

Most growers import vine-cut transplant material (slips) from certified U.S. propagators. Slips can be produced successfully in Ontario by bedding selected roots in a greenhouse. In Ontario, Beauregard and Covington are the most commonly grown varieties.

Planting and Spacing

A finger-type vegetable transplanter is suitable for setting out slips.

Row Spacing:	102–112 cm	40–44 in.
In-row Spacing:	30–40 cm	12–16 in.
Target population:	24,700 plants/ha	10,000 plants/acre

Sweet potatoes are mechanically cultivated several times to warm the soil, control weeds and enhance hill formation to ease digging. Hills approximately 15 cm (6 in.) high and 40 cm (16 in.) wide should be in place prior to root initiation and vine growth.

Sweet potatoes are generally drought tolerant to Ontario climactic conditions. During extremely dry periods from June to August, it may be necessary to apply two to three irrigations of 3.5 cm (1.4 in.) each.

Integrated Pest Management

Diseases

STEM ROT AND SCURF

Scurf is a fungal disease that can be transmitted on transplants. For more information on damping-off and root rots, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59. Ensure slips are disease-free and follow a 3–4-year rotation between sweet potato crops. See Table 9–100, *Sweet Potato Insect and Disease Control Recommendations*, on page 196.

SWEET POTATO FEATHERY MOTTLE VIRUS

Virus symptoms include chlorotic spots, often with purple borders, and mild stunting of plants. Symptoms vary with virus strain and sweet potato variety. Obvious symptoms are not always present. Most strains are not thought to have a significant impact on yield, however, some strains can cause symptoms on storage roots. The disease is transmitted in a non-persistent manner by aphids and can be transferred on infected slips. The main method of control is avoiding diseased plants through use of clean, virus-free planting material. For more information, see the sections *Aphids*, on page 60, and *Viruses (General)*, on page 59.

Post-Harvest Diseases

Sweet potatoes are susceptible to a number of fungal and bacterial pathogens that enter tubers through wounds inflicted during harvesting and handling, causing rots in storage or during transport.

Reduce the number of potential infection sites by minimizing injuries to roots during harvest and handling. If possible, harvest under dry soil conditions. Avoid chilling injury by harvesting before the first killing frost. Cure as soon as possible after harvest to heal wounds.

See Table 9–100, *Sweet Potato Insect and Disease Control Recommendations*, on page 196.

Insects

WIREWORMS, WHITE GRUBS

For identification and management information on these common vegetable insects affecting sweet potatoes, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, and Table 9–100, *Sweet Potato Insect and Disease Control Recommendations*, on page 196.

FLEA BEETLES

Adults are small, dark beetles that feed on foliage. The "shot-hole" feeding damage is not thought to significantly affect yields. In most areas where sweet potatoes are grown, larvae will also attack roots, leaving shallow, winding trails on the surface. Damage commonly occurs on the fibrous non-marketable roots.

Table 9–100.
Sweet Potato
Insect and Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
STEM ROT AND SCURF						
carbamate (group M3)	thiram	Thiram 75 WP	1.75 kg per 1,000 L water			Dip roots of sprouts for 30 seconds in suspension, then plant promptly.
EUROPEAN CHAFER GRUBS						
neonicotinoid (group 4)	imidacloprid	Admire 240 F	1.2 L	0.48 L	125	Apply as a soil drench after transplant. Make only 1 application/yr. 24-hr re-entry.
FLEA BEETLES, LEAFHOPPERS						
pyrethroid (group 3)	lambda-cyhalothrin	Matador 120 EC	83 mL	33 mL	7	Maximum 3 applications/yr. Allow 7 days between applications. 24-hr re-entry.
POST-HARVEST DISEASES						
inorganic (group M1)	hydrogen peroxide	StorOx	100 mL per 10 L water			Spray diluted solution on newly harvested tubers. Additional applications can be made daily as a direct injection into humidification water.

[1] PHI = Pre-Harvest Interval

Nematode Control

See the section *Nematodes*, on page 63.

Harvesting, Curing and Storage

In Ontario, the sweet potato harvest generally starts in early September and continues through October. Mow and side-cut the surface vine growth approximately 1 week before the scheduled harvest. Take care not to wound the tender skin of the sweet potato. It is not uncommon to cull 30-40% of the undersized, wounded or misshapen roots in the field.

Move the sweet potatoes into the curing/conditioning facility immediately after digging. During curing, maintain temperatures of 25°C–28°C (76°F–82°F) and relative humidity of 85%–95% for 5–7 days. Once cured, sweet potatoes can be stored for several months at 13°C.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

TOMATOES

Production Requirements

Tomatoes perform well on a wide range of mineral soil types, but good drainage is essential. Lighter soils produce earlier crops and facilitate mechanical harvesting. A soil pH range of 6.0–6.8 is optimal.

In Ontario, tomatoes are established using greenhouse-produced transplants. Fresh-market varieties grown in Ontario require 58–80 days from transplanting to harvest. Processing varieties require from less than 100 to over 130 days. Harvest begins 6–10 weeks after pollination.

Average Yields

Crop	per acre	per hectare
Fresh market	8–14 tons	18–31 tonnes
Cherry tomatoes	2.5–3.5 tons	5.5–8 tonnes
Processing	32–40 tons	72–90 tonnes

Cultivars

Fresh-market tomato growers are encouraged to conduct their own field trials to evaluate varieties under local growing conditions. See Appendix D, *Vegetable Seed Suppliers*, on page 229. Growers of tomatoes for processing must grow varieties specified by the processor.

See the section *Transplanting*, on page 39, for information on producing tomato transplants.

Plasticulture

Fresh-market tomatoes respond well to plastic mulch, row covers and drip irrigation. However, keep in mind that tomatoes are sensitive to low temperatures. Row covers may not provide significant frost protection. Monitor the temperature inside the row cover regularly and ventilate when it reaches 35°C (95°F) or higher. Remove the cover once conditions are favourable for good growth and prior to pollination. To control weed growth under the mulch, choose a mulch that blocks most light transmission, such as black, white on black, or infrared-transmitting mulch. High tunnels are another option to extend the field tomato production season. For more information, see the section *Season Extension*, on page 34.

Plant Spacing

Table 9–101, *Tomato Plant Spacing*, right, shows spacing for both fresh-market and processing types of tomatoes.

Table 9–101.
Tomato Plant Spacing

Type	Row Spacing	In-Row Spacing	Bed Centres
Fresh Market			
Large vined (indeterminate)	1.5–1.8 m (5–6 ft)	50–70 cm (20–27 in.)	
Small vined (determinate and semi-determinate)	0.9–1.5 m (3–5 ft)	30–60 cm (12–24 in.)	
Processing (Machine Harvest)			
Twin row system	45 cm (18 in.)	38-45 cm[1] (15–18 in.)	1.5–1.65 m (5–5.5 ft)
Single row system	75 cm (30 in.)	38-45 cm[1] (15–18 in.)	

[1] For small-vined, early-season processing varieties, in-row spacing can be reduced to 33-38 cm (13-15 in.).

Machine harvest varieties may be grown in twin or single rows, with or without raised beds, depending on the harvest equipment. The improved air circulation associated with single rows may help to reduce foliage and fruit disease.

Fertility

Nitrogen

FRESH-MARKET TOMATOES

For non-fertigated fresh market tomatoes, apply nitrogen according to Table 9–102, *Non-Fertigated Tomato Nitrogen Recommendations*, below. Avoid late side-dress applications. They may prune the roots and trigger blossom-end rot.

Table 9–102.
Non-Fertigated Tomato Nitrogen Recommendations

	Actual N	
	kg/ha	lb/acre
Fresh-Market		
Preplant	35–50	31–45
Side-dress (applied after the first fruit are set)	35–50	31–45
Processing – Hybrid		
Coarse sand and sandy loams <2% organic matter	160–180	142–160
Loams, silt loams and sandy loams >2% organic matter	90–120	80–107
Processing – Open-Pollinated		
Coarse sand and sandy loams <2% organic matter	100–120	89–107
Loams, silt loams and sandy loams >2% organic matter	70–90	62–80

Table 9–103. Fertigated Tomato Nitrogen Recommendations

Timing	Actual N	
	kg/ha	**lb/acre**
Fresh Market Tomatoes – on all soils **Processing Tomatoes – on all soils (except coarse-textured soils containing less than 3.2% organic matter)**		
Preplant (broadcast)	35–50	31–45
Transplanting to fruit set	2.5/week	2.2/week
Fruit sizing to harvest	5/week	4.5/week
Harvest	2.5/week	2.2/week
Processing Tomatoes – on coarse-textured soils containing less than 3.2% organic matter only		
Preplant (broadcast)	85–120	77–107
Week 1–3 (transplant to first bloom)	no fertigation	
Week 4 (beginning of fruit set)	20–25/week	18–22/week
Week 5–7 (beginning of fruit sizing)	25–35/week	22–31/week
Week 8–9	20–25/week	18–22/week
Week 10	continue irrigation, no fertigation	
Week 11 to harvest	no irrigation/fertigation	

Do not exceed 300 kg/ha (270 lb/acre) total nitrogen applied during the season.

For fertigated fresh market tomatoes, apply nitrogen according to the schedule in Table 9–103, *Fertigated Tomato Nitrogen Recommendations*, above.

PROCESSING TOMATOES

The nitrogen rate will vary greatly, according to variety, soil type, crop rotation, organic matter and soil management.

For tomatoes that are not fertigated, apply nitrogen as a preplant broadcast application according to the recommendations in Table 9–102, *Non-Fertigated Tomato Nitrogen Recommendations*, on page 197.

For fertigated tomatoes, broadcast and incorporate the recommended preplant nitrogen. Apply the remainder of the nitrogen according to Table 9–103, *Fertigated Tomato Nitrogen Recommendations*, above.

The nitrogen rate for fertigated processing tomatoes on coarse textured soils with organic matter levels of 2.5%–3.2% is very specific to these soils. The supporting research was conducted near Harrow, on Granby sandy loam and Granby loamy sand soils. There is no research showing a benefit of this higher fertigation rate on other soil types. All other soils should use the alternative fertigation recommendation.

Timely establishment of cover crops is recommended following the harvest of vegetable crops, to manage residual soil nitrogen and nitrogen release from plant residue.

Table 9–104. Fertigated Tomato Potassium Recommendations

Timing	Actual K_2O	
	kg/ha	**lb/acre**
Preplant	35–50	31–45
Transplanting to fruit set	2.5/week	2.2/week
Fruit sizing to harvest	5/week	4.5/week
Harvest (fresh market)	2.5 /week	2.2/week

Alternatively, potassium can be applied 100% preplant, according to Table 1–12, on page 15.

Phosphorus

Test the soil to determine phosphorus requirements. Where the soil test values are 61 mg P per L soil (ppm) or higher, tomatoes are unlikely to respond to additional phosphate applications. For soils testing lower than 61 mg P per L soil (ppm), see Table 1–10, *Phosphorus Requirements: Vegetables on Mineral Soils*, on page 12.

All phosphorus should be broadcast preplant. When fertigating, never apply phosphorus through the drip line.

Potassium

Test the soil to determine potassium requirements. Where the soil test values are 181 mg K per L soil (ppm) or higher, fresh-market and paste tomatoes are unlikely to respond to additional potash applications. For whole-pack tomatoes, use a higher threshold of 250 mg K per L soil (ppm).

For soils testing lower than the threshold values listed above, see Table 1–12, *Potassium Requirements: Vegetables on Mineral Soils*, on page 15. For fertigated tomatoes, potash can be applied 100% preplant, or split between preplant and fertigated, according to the recommendations in Table 9–104, *Fertigated Tomato Potassium Recommendations*, above.

STARTER SOLUTION (ALL TOMATOES)

Apply a high-phosphorus starter fertilizer in the transplant water when transplanting tomatoes. Starter fertilizer is especially important when planting in cool soils.

Table 9–105. Tomato Starter Solution Recommendations

Soil Temperature	Starter Concentration[1]
<18°C (64°F)	Use full label rate as recommended.
18°C–27°C (64°F–81°F)	Use half of recommended rate.
>27°C (81°F)	Starter not normally required.

[1] Under high temperature or dry conditions or in sandy soils with less than 2% organic matter, use half the recommended rates.

Table 9–106.
Tomato Nutrient Sufficiency Ranges

Plant Part	Time of Sampling	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
		Percent (%)						Parts Per Million (ppm)				
Most recently mature leaf	5-leaf stage	3–5	0.3–0.6	3–5	1–2	0.3–0.5	0.3–0.8	40–100	30–100	25–40	20–40	5–15
	First flower	2.8–4	0.2–0.4	2.5–4	1–2	0.3–0.5	0.3–0.8					
	Early fruit set	2.5–4	0.2–0.4	2.5–4	1–2	0.25–0.5	0.3–0.6	40–100	30–100	20–40	20–40	5–10
	First ripe fruit	2–3.5	0.2–0.4	2–4	1–2	0.25–0.5	0.3–0.6					
	During harvest period	2–3	0.2–0.4	1.5–2.5	1–2	0.25–0.5	0.3–0.6					

Adapted from Maynard, D.N., and G.J. Hochmuth. 2007. *Knott's Handbook for Vegetable Growers*. 5th edition. John Wiley & Sons, Inc. New York.

Starter fertilizers are available in several forms, including liquids (10-34-0 or 6-24-6), soluble, or granular materials (10-30-20 or 10-52-10). Apply according to the recommendations in Table 9–105, *Tomato Starter Solution Recommendations*, on page 198.

Magnesium

A magnesium deficiency may occur on tomatoes. The usual symptoms are yellowing of older leaves while the veins remain dark green. Excessive potash applications may induce a magnesium deficiency. Reduce potassium fertilizer rates on soils testing less than 100 ppm magnesium. Adjust the potassium rate proportionally to a minimum of 50% at 50 ppm Mg. See the section *Micronutrients*, on page 17, and Table 1–13, *Application Rates for Magnesium, Calcium and Micronutrients*, on page 16.

Plant Analysis

When used in conjunction with a soil analysis, plant analysis is a useful tool for diagnosing crop problems or for evaluating a fertilizer program. The objective of a good fertilizer program is to maintain tissue nutrient concentrations on the lower side of the sufficiency range. Attempting to bring the nutrient analysis up to the higher end of the range could possibly result in over-fertilization and may not be economical. For more information see the section, *Plant Analysis*, on page 3.

Only use sufficiency ranges as a reference and a guideline. Plant analysis does not replace soil testing or a sound soil fertility program. See Table 9–106, *Tomato Nutrient Sufficiency Ranges*, above.

Integrated Pest Management

Transplant Production — Disease Management

Bacterial spot is a serious disease of tomatoes. Talk to your seed supplier to ensure that proper seed treatment prevention methods have been used. A greenhouse spray program with a fixed copper fungicide can greatly reduce the field infection rate later in the season. Apply every 5 days, starting 2 $^{1}/_{2}$ weeks after seeding. Use low water volumes — wet the foliage, but not to excessive runoff. Ensure foliage is dry when shipping plants.

Fungicides registered for greenhouse transplant production are listed in Table 9–107, *Greenhouse Tomato Transplant Production Disease Control Recommendations*, on page 200. See also the section *Bacterial Disease Control With Copper Fungicides*, on page 202. For more information on vegetable transplant production, see Chapter 5, *Seeding and Transplanting*, on page 37.

Diseases

ANTHRACNOSE

Identification: Fruit symptoms appear as small, sunken, water-soaked, circular spots. Lesions gradually expand to 20 mm ($^{3}/_{4}$ in.) in diameter, developing a pattern of concentric rings. The lesions darken, and small black fungal structures appear in the centre. Anthracnose lesions on leaves are inconspicuous.

Development: Infections can take place under a wide range of temperatures from 10°C–30°C (50°F–86°F). Rapid development occurs during periods of prolonged leaf wetness. While symptoms appear only on ripe fruit, infection can be initiated on green fruit. It is critical that green fruit be adequately protected with a fungicide program.

Thresholds: See the section *TOMcast*, on page 200. There is little tolerance for anthracnose in processing crops, where fruit must be held in the field and the taste of the product can be affected. Do not delay initial fungicide applications beyond July 11 (July 18 for very late plantings).

Management Notes: Follow a minimum 3-year rotation with non-solanaceous crops. Control weeds that can act as hosts. Use disease-free or treated seed. Properly timed fungicide sprays are effective at reducing losses to this

Table 9–107.
Greenhouse Tomato Transplant Production Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	Notes
DAMPING-OFF, ROOT ROT					
phthalimide (group M3)	captan	Maestro 80 DF	1.25 kg/1,000 L of water. Apply 50–85 L of solution per 100 m^2 (1,076 ft^2).		Soil drench treatment. 48-hr re-entry.
		Supra Captan 80 WDG			
dithiocarbamate (group M2)	oxine benzoate	No-Damp	10 mL/L of water		Damping off. Soil treatment.
BOTRYTIS GREY MOULD					
hydroxyanilide (group G3)	fenhexamid	Decree 50 WDG	1.5 kg	607 g	Maximum 2 applications per crop cycle. 60 day pre-harvest interval. 4-hr re-entry.
BACTERIAL DISEASE					
inorganic (group M1)	copper hydroxide	Kocide 2000	3.2 kg	1.3 kg	Apply every 5 days, when warranted, to a maximum of 5 applications over a 4-week period prior to transplanting. Apply in low water volumes. 24-hr re-entry.

disease. See Table 9–108, *Tomato Fungal Disease Control Recommendations*, on page 201.

EARLY BLIGHT

Identification: Circular spots with dark, concentric rings (target spots) develop on the older foliage. Severe infections spread to younger leaves. Fruit infections are not common, but may appear as a blackened area at the stem-end.

Development: Early blight overwinters in infected crop residue. Spores are present throughout the growing season and may be carried long distances in the wind. Temperatures of 17°C–24°C (63°F–75°F) and extended leaf wetness favour early blight development.

Thresholds: See the section *TOMcast*, right.

Management Notes: Reduce early blight inoculum by following a 3- to 4-year crop rotation. Ensure transplants are healthy and free of disease. Cultivars vary in tolerance to early blight. See Table 9–108, *Tomato Fungal Disease Control Recommendations*, on page 201.

SEPTORIA LEAF SPOT

Identification: Lower leaves become peppered with small, dark, circular spots up to 5–6 mm ($^{1}/_{4}$ in.) in diameter. Spots have a dark margin with a lighter centre. Tiny, black fungal structures (pycnidia) are visible in the centre of the lesions. Rapid defoliation may occur if left untreated.

Development: Plants are most susceptible after fruit set. Septoria leaf spot prefers warm temperatures of 20°C–25°C (68°F–77°F) and extended periods of leaf wetness caused by overhead irrigation, rain or heavy dews.

Thresholds: See the section *TOMcast*, below.

Management Notes: Ensure disease-free seed and transplants. Rotate crops and control solanaceous weeds, such as nightshade. See Table 9–108, *Tomato Fungal Disease Control Recommendations*, on page 201.

TOMcast

The TOMcast program is available in some growing areas to help field tomato growers determine the optimum time to apply foliar fungicides for the control of early blight, septoria leaf spot and anthracnose.

A network of weather stations monitors conditions affecting disease development. The weather data is used to calculate disease severity values (DSVs) throughout the growing season. Growers are advised to spray when a critical number of DSVs have accumulated since planting or since the last fungicide application. For more information, contact Weather Innovations Incorporated at 519-352-5334 or see their website at www.weatherinnovations.com.

If the TOMcast service is unavailable, begin a preventative spray program when the first fruits are about walnut size. Repeat sprays as necessary. Repeat at 5–7-day intervals during continuous moist weather. Extend the schedule to 12–14 days in warm, dry weather if diseases are under control. Applications should continue until close to harvest. Anthracnose lesions can appear on unprotected fruit within 5–6 days in favourable conditions.

Table 9–108.
Tomato
Fungal Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
ANTHRACNOSE, EARLY BLIGHT, LATE BLIGHT, SEPTORIA LEAF SPOT						
chloronitrile (group M4)	chlorothalonil	Bravo 500	2.4–4.0 L	0.97–1.62 L	1	48-hr re-entry.
dithiocarbamate (group M2)	mancozeb	Dithane DG	1.1–3.25 kg	0.45–1.3 kg	7	**Early blight, anthracnose, late blight only.**
		Manzate Pro-Stick	1.75–3.25 kg	0.7–1.3 kg	7	
		Penncozeb 80 WP	1.1–3.25 kg	0.45–1.3 kg	7	
	metiram	Polyram DF	2.25–3.25 kg	0.9–1.3 kg	7	Low rate for early and late blight; high rate for anthracnose and septoria leaf spot.
Qol (group 11)	azoxystrobin	Quadris Flowable	300–500 mL	120–200 mL	1	**Early blight, anthracnose only.** Maximum 3 applications/yr. Do not apply for 21 days after transplanting. Do not apply for 6 days before or after using metribuzin.
	pyraclostrobin	Cabrio EG	560–840 g	226–340 g	0	Use up to 1 kg/ha (400 g/acre) for late blight. Maximum 6 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group.
carboxamide (group 7)	boscalid	Lance WDG	175–315 g	70–126 g	0	**Early blight only.** Maximum 5 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 4-hr re-entry.
Qol + acetamide (group 11 + group 27)	famoxadone + cymoxanil	Tanos 50 DF	560–840 g	226–340 g	3	**Early blight and late blight only.** 24-hr re-entry. Do not apply sequential applications of any Qol fungicide or of any tank-mix containing a Qol fungicide.
inorganic + dithiocarbamate (group M1 + group M2)	copper hydroxide + mancozeb	Parasol Flowable + Dithane DG	2.3 L + 1.75–2.25 kg	0.9 L + 0.7–0.9 kg	7	**Septoria leaf spot, early blight and late blight only.** Apply at 7–10-day intervals.
		Parasol Flowable + Manzate Pro-Stick	2.3 L + 1.75–2.25 kg	0.9 L +0.7–0.9 kg	7	**Early blight and septoria leaf spot only.** Use the high rate for early blight. Apply at 7-day intervals.
inorganic (group M1)	copper hydroxide	Kocide 2000	2.24–2.52 kg	0.91–1.0 kg	1	
phthalimide (group M3)	captan	Maestro 80 DF	2.75–4.25 kg	1.1–1.7 kg	2	**Anthracnose and septoria leaf spot only.** Use high rate on mature plants or for severe infections. 48-hr re-entry.
		Supra Captan 80 WDG	2.75–4.25 kg	1.1–1.7 kg	2	
BOTRYTIS GREY MOULD						
carboxamide (group 7)	boscalid	Lance WDG	420 g	168 g	0	Maximum 5 applications/yr. Do not make more than 2 applications before rotating to a different fungicide group. 4-hr re-entry.

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[1] PHI = Pre-Harvest Interval.

BACTERIAL SPOT AND BACTERIAL SPECK

Identification: It can be difficult to distinguish between these two diseases. Small, dark lesions develop on the leaves. The infected tissue of either disease may exhibit a yellow halo. Lesions also occur on stems and flower buds. Severe infections may cause defoliation.

Table 9–109.
Tomato
Bacterial Disease Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
inorganic + dithiocarbamate (group M1 + group M2)	copper hydroxide + mancozeb	Kocide 2000 + Dithane DG	3.2 kg + 1.75–2.25 kg	1.3 kg + 0.7–0.9 kg	7	Only effective if applied 7 days after transplanting and repeated at 7-day intervals for at least 3 applications. Apply more frequently under wet conditions. If wet conditions persist, applications may be continued until early bloom. 24-hr re-entry.
		Parasol Flowable + Dithane DG	2.3 L +1.75–2.25 kg	0.9 L + 0.7–0.9 kg	7	
		Parasol Flowable + Manzate Pro-Stick	2.3 L +1.75–2.25 kg	0.9 L +0.7–0.9 kg	7	

[1] PHI = Pre-Harvest Interval.

These diseases initiate lesions on green fruit. Bacterial spot–infected fruit develop small, raised, dark spots. Young lesions may have a white halo, similar to bacterial canker. Spots increase in size to 4–6 mm (1/4 in.) in diameter and develop brown, corky centres.

Bacterial speck fruit lesions are small (<2 mm in diameter), black, slightly raised and often surrounded by a narrow, green-to-yellow halo. Speck lesions on the fruit are usually superficial and can be scraped off.

Development: Bacterial spot prefers warm temperatures of 24°C–30°C (75°F–86°F). Bacterial speck favours cooler weather — 18°C–24°C (64°F–75°F). Abundant rainfall and high humidity aid infection of both diseases.

Thresholds: None established. Tolerance for either disease is low in fresh-market or processing tomatoes (wholepack and diced) due to marketability and peeling issues.

Management Notes: All tomato seed should be disinfected by the supplier, using acid or chlorine treatment. Do not plant diseased transplants. Copper fungicides may be effective in slowing bacterial spot development, but only if applied early and often. Bacterial speck populations in Ontario show resistance to copper. See Table 9–109, *Tomato Bacterial Disease Control Recommendations*, above.

Note: Avoid working in fields when foliage is wet. Wash machinery with a high-pressure hose after working in contaminated fields. If possible, schedule overhead irrigation early in the day to allow the foliage time to dry before nightfall or consider a drip irrigation system.

BACTERIAL CANKER

Identification: Early (systemic) infections from infected seed or seedlings are of greatest concern. They cause the plant to wilt, often on only one side. Streaking or open cankers may appear on the stems and a light, reddish-brown discolouration may be seen in the vascular tissue, just above the soil line.

The more common, and less severe, secondary infections show up later in the season. Leaves develop brown-to-black margins with a thin, yellow border. Leaflet edges usually curl upwards.

Infected fruit may develop "bird's-eye" spots — small lesions with light brown centres and a greasy white halo.

Bacterial Disease Control With Copper Fungicides

In the greenhouse, apply 4–5 applications of a registered fixed copper product, every 5 days, starting 16–18 days after seeding. Use low water volumes. Wet the foliage, but do not soak the plug media. Apply fungicides after the last watering of the day. Ensure foliage is dry when shipping plants.

In the field, apply a copper spray within 7 days of transplanting; within 5 days if the weather is wet (rain, fog, dews) or the greenhouse program was not followed.

Repeat copper applications at 7-day intervals for at least 3 applications. Continue applications until early fruit set if wet conditions prevail or if plants are under stress. Bacterial speck populations in Ontario show resistance to copper.

Research has shown that tank-mixing mancozeb with copper enhances bacterial disease control.

Development: Warm, wet weather conditions with temperatures of 24°C–32°C (75°F–90°F) favour the spread of this disease.

Management Notes: Use disease-free or disinfected seed and disease-free transplants. Copper fungicides may slow canker development. See the section *Bacterial Disease Control With Copper Fungicides* and Table 9–109, *Tomato Bacterial Disease Control Recommendations*, on page 202.

For more information on bacterial diseases, see the OMAFRA Factsheet, *Bacterial Diseases of Tomato: Bacterial Spot, Bacterial Speck, Bacterial Canker*, Order No. 05-069.

LATE BLIGHT

Identification: Late blight causes rapid and severe defoliation. Pale green-to-brown water-soaked spots develop on the leaves. Lesions enlarge rapidly and become brown to purplish-black. A grey-to-white mouldy growth may develop on the underside of infected leaves, especially under conditions of high humidity. Brownish cankers on leaf petioles and stems may girdle and kill the plant. Fruit lesions are firm and greasy-looking, with greyish-green or brown blotches.

Development: The late blight fungus prefers temperatures from 15°C–21°C (59°F–70°F). Cool nights and warm days, with moist weather, are ideal for disease development.

Thresholds: No tolerance. This disease is easily spread by wind and can rapidly destroy the crop.

Management Notes: Preventative fungicide sprays for early blight, septoria and anthracnose also protect against late blight. If the disease is present in the area, follow a 5–7-day fungicide schedule, using fungicides recommended specifically for late blight control. For more information about management practices for reducing late blight, see the section *Late Blight*, on page 157. See also Table 9–108, *Tomato Fungal Disease Control Recommendations*, on page 201.

VERTICILLIUM WILT

Identification: Yellow, V-shaped lesions develop on the lower leaves. Symptoms often appear only on one side of the plant or one side of the leaf. The vascular tissue becomes brown and discoloured, causing infected plants to wilt, especially during the hot part of the day.

Development: Verticillium wilt is present all season. However, symptoms are often more severe after fruit set or during dry periods. The presence of plant parasitic nematodes may increase the severity of verticillium wilt.

Thresholds: Soil *Verticillium*, root knot and root lesion nematode counts, available from the Pest Diagnostic Clinic, University of Guelph, will help determine the need for control measures. See Appendix G, *Diagnostic Services*, on page 233.

Management Notes: Follow a 4–6-year crop rotation. Do not rotate with related crops, strawberries or raspberries. Keep fields clean of host weeds such as nightshades. Cultivars tolerant to verticillium wilt are available. Soil fumigation may be required if *Verticillium* and nematode counts are high. See the section *Nematodes*, on page 63.

VIRUSES (CUCUMBER MOSAIC, TOMATO MOSAIC, STREAK, TOMATO SPOTTED WILT)

Identification: Symptoms vary between viruses, cultivars and conditions. Interaction between viruses may occur, complicating visual diagnosis.

Period of Activity: Cucumber mosaic is spread by aphids. Thrips are a vector for tomato spotted wilt. The presence of these diseases usually follows periods of high aphid/thrips activity. Tomato mosaic and the streak viruses are spread mechanically.

Management Notes: Control weed hosts in and around the field. Pigweeds, nightshades and related weeds, milkweed, purslane, chickweed and many other plants are alternative hosts to the cucumber mosaic virus. See the section *Aphids*, on page 60. Tomato spotted wilt virus is rarely of economic concern.

Insects

CUTWORMS, TARNISHED PLANT BUG, WIREWORM, APHIDS

For identification and management information on these common vegetable insects affecting tomatoes, see Chapter 8, *General Diseases and Insects of Vegetable Crops*, on page 59, Table 9–110, *Tomato Aphid and Colorado Potato Beetle Control Recommendations*, on page 205, and Table 9–111, *Tomato Insect Control Recommendations*, on page 206.

COLORADO POTATO BEETLE

Identification: Adults are orange with 10 black stripes on the wings. Larvae are red-to-orange with two rows of black spots along their sides.

Period of Activity: Feeding damage is mainly a concern early in the season when plants are small.

Thresholds: 0.5 adults or larvae per plant in the first 2 weeks after transplanting or 1 adult or larvae per plant later in the season.

Management Notes: Rotate crops and avoid planting tomatoes adjacent to beetle overwintering sites (previous year's tomato, eggplant or potato fields). Chemical controls are most effective when applied to small larvae. For more information, see the section *Colorado Potato Beetle*, on page 163. See Table 9–110, *Tomato Aphid and Colorado Potato Beetle Control Recommendations*, on page 205.

Warning

In a number of counties and regions, Colorado potato beetles have developed a strong resistance to certain insecticides. To slow development of further resistance, it is essential to rotate between chemical groups each time a spray is applied.

TOMATO OR TOBACCO HORNWORM

These hornworms are large, smooth, green caterpillars. Mature larvae measure 8 cm (3.5 in.) in length. The hornworm has seven or eight conspicuous white V-shaped markings down each side and a prominent spike (horn) on its rear end. The hornworm feeds on the leaves, stems and fruit of tomato plants.

If populations exceed one larvae per 30 plants, apply one of the products listed in Table 9–111, *Tomato Insect Control Recommendations*, on page 206.

CABBAGE LOOPER

The cabbage looper is a sporadic pest of tomatoes. Use a spray threshold of 15 larvae per 30 plants. For complete identification and management information, see the section *Imported Cabbageworm, Cabbage Looper, Diamondback Moth Caterpillar*, on page 90. Also see Table 9–111, *Tomato Insect Control Recommendations*, on page 206.

STINK BUG, TARNISHED PLANT BUG

Stink bugs feed on tomato fruit. Their piercing mouthparts sting the fruit, producing a yellowish blotch and corky tissue beneath the skin. Damaged fruit does not peel well during processing. Tarnished plant bug causes similar damage. Stink bugs often move into tomatoes from wheat fields or weedy areas as they dry out in midsummer.

SAP BEETLES

Sap beetles are attracted to damaged or rotting fruit. Establish roadways or dedicated spray rows in the field at suitable intervals to minimize damage caused by farm equipment. Avoid crushing of fruit at picking time.

For processing crops, harvest as close as possible to time of delivery to the factory. If loaded wagons are not delivered immediately, leave them exposed to air circulation.

Birds

Bird-feeding damage on tomato fruit results in reduced yields and quality, as well as increased sorting costs. Noisemakers, such as propane cannons and digital distress calls may be successful deterrents. Use more than one type of scare device. Regular changes to the noise frequency pattern and distribution of these scare tactics will improve their efficacy. Start control measures early, before birds get accustomed to feeding in your field. See the section *Birds*, on page 64.

Overall population control is not feasible. Gulls, crows, cowbirds, starlings, grackles and blackbirds are protected under the Wildlife Conservation Act. However, growers may acquire a permit to use a firearm to scare or shoot birds causing damage to crops. For a permit, call the Enforcement Coordinator, Canadian Wildlife Service, Environment Canada, 905-336-4464.

Physiological Disorders

Blossom-End Rot (BER)

Blossom-end rot is a localized calcium deficiency in the blossom end of the fruit. It occurs when dry soil conditions reduce the amount of water movement into the plant, thus reducing the movement of calcium to the fruit. Calcium is an important component of cell development. BER is caused primarily by dry soil conditions, not by a deficiency of calcium in the soil.

Side-dressing with calcium nitrate will not prevent BER if adequate moisture is not available. Foliar sprays of calcium are also ineffective. Foliar-applied calcium is taken up and fixed in the leaves, and very little reaches the fruit. Avoid deep cultivation, which can prune roots and reduce water uptake. Blossom-end rot can be minimized by properly scheduled irrigation, ensuring steady movement of water and calcium into the plant. (See the section *Irrigation*, on page 27.)

Table 9–110.
Tomato
Aphid and Colorado Potato Beetle Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
APHIDS						
neonicotinoid (group 4)	acetamiprid	Assail 70 WP	56–86 g	22.4–34.4 g	7	Maximum 2 applications/yr. Alternate applications with other insecticide groups. 12-hr re-entry.
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	1.5–2.75 L	0.6–1.1 L	2	
		Thionex 50 WP	1.1 kg	0.45 kg	2	
organophosphate (group 1B)	diazinon[2]	Diazinon 50 W	1.1–1.75 kg	0.45–0.71 kg	1	
		Diazinon 500 E	1.1–1.7 L	0.45–0.69 L	1	
	dimethoate	Cygon 480	0.55–1.1 L	0.22–0.45 L	7	
		Lagon 480	0.55–1.1 L	0.22–0.45 L	7	
	malathion[2]	Malathion 25 W	2.75–4.25 kg	1.1–1.7 kg	3	Not effective below 20°C (68°F). 24-hr re-entry.
		Malathion 500 E	1.5–2.0 L	0.6–0.8 L	3	
	acephate	Orthene 75 SP	1.2 kg in 2,000 L of water	0.48 kg in 180 gal of water		Based on 14,000 plants/ha. Transplanting water treatment only. ***Caution:*** Temporary plant damage may occur on light sandy soils or if the rate used is too high.
carbamate (group 1A)	methomyl	Lannate TNG	270–540 g	109–218 g	1	24-hr re-entry.
COLORADO POTATO BEETLE						
Transplant treatment						
neonicotinoid (group 4)	imidacloprid	Admire 240 F	7–10 mL per 100 m of row	2–3 mL per 100 ft of row		Apply in-furrow at transplanting. Consult the label for application details. Do not apply foliar imidacloprid in the same season as a soil application.
		Alias 240 EC	7–10 mL per 100 m of row	2–3 mL per 100 ft of row		
organophosphate (group 1B)	acephate	Orthene 75 SP	1.2 kg in 2,000 L of transplant water	0.48 kg in 180 gal of transplant water		Based on 14,000 plants/ha. ***Caution:*** Temporary plant damage may occur on light sandy soils or if the rate used is too high.
Foliar treatment						
biological (group 11)	*Bacillus thuringiensis*	Novodor	4.0–8.0 L	1.6–3.2 L	0	Field scouting is essential for timing of sprays.
neonicotinoid (group 4)	imidacloprid	Admire 240 F	200 mL	80 mL	7	Maximum 2 foliar spray applications at least 5 days apart may be made per year. Do not make a foliar application following a transplant application of imidacloprid in the same crop. 24-hr re-entry.
		Alias 240 EC	200 mL	80 mL	7	
	acetamiprid	Assail 70 WP	40–80 g	16–32 g	7	Maximum 2 applications/yr. Alternate applications with other insecticide families. 12-hr re-entry.
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	83–125 mL	34–51 mL	7	Use the higher rate for larger instars or higher populations of larvae. 24-hr re-entry.
	deltamethrin	Decis 5 EC	100–150 mL	40–60 mL	3	Maximum 3 applications/yr (1/yr on muck soils). Do not apply after August 1.
	cypermethrin	Ripcord 400 EC	85 mL	34 mL	3	
	permethrin	Pounce 384 EC	180–260 mL	73–105 mL	0	
naturalyte (group 5)	spinosad	Success 480 SC	83 mL	34 mL	1	Use only on small larvae and low infestations. Maximum 3 applications/yr. Maintain a spray water pH of 6 or greater.
		Entrust 80 W	50 g	20 g	1	

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[1] Pre-Harvest Interval.

[2] Control of aphids with diazinon and malathion has been inconsistent in many areas.

Table 9–111.
Tomato
Insect Control Recommendations

Group (Group #)	Common Name	Trade Name	Rate per Hectare	Rate per Acre	PHI[1]	Notes
CUTWORMS						
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	83 mL	34 mL	7	Apply in the late evening or at night. Do not disturb the soil for 5 days after application. 24-hr re-entry.
	permethrin	Pounce 384 EC	180–260 mL	73–105 mL	0	Apply in the late evening or at night.
carbamate (group 1A)	carbaryl	Sevin XLR	45 mL/100-m row	14 mL/100-ft row	2	
	methomyl	Lannate TNG	270–540 g	109–218 g	1	Use the high rate on large larvae (2.5–3.0 cm). 24-hr re-entry.
organophosphate (group 1B)	acephate	Orthene 75 SP	1.2 kg in 2,000 L of water	0.48 kg in 180 gal of water		Also controls wireworm. Based on 14,000 plants/ha. Transplanting water treatment only. ***Caution:*** Temporary plant damage may occur on light sandy soils or if the rate used is too high.
TARNISHED PLANT BUG						
pyrethroid (group 3)	cyhalothrin-lambda	Matador 120 EC	83 mL	34 mL	7	24-hr re-entry.
organophosphate (group 1B)	dimethoate	Lagon 480	0.55–1.1 L	0.22–0.45 L	7	
carbamate (group 1A)	carbaryl	Sevin XLR	5.25–6.4 L	2.1–2.6 L	2	
HORNWORM						
biological (group 11)	*Bacillus thuringiensis*	Thuricide HPC	0.75–1.5 L	0.3–0.6 L	0	Most effective against small larvae.
		Dipel 2X DF	140–275 g	56–110 g	0	
		Biprotec CAF	0.65–1.1 L	0.26–0.44 L	0	
pyrethroid (group 3)	permethrin	Pounce 384 EC	180–260 mL	73–105 mL	0	
carbamate (group 1A)	carbaryl	Sevin XLR	2.5–5.25 L	1.0–2.1 L	2	
chlorinated cyclodiene (group 2A)	endosulfan	Thiodan 4 EC	1.5–2.75 L	0.6–1.1 L	2	
		Thionex 50 WP	1.1 kg	0.45 kg	2	
DROSOPHILA (FRUIT FLY)						
organophosphate (group 1B)	diazinon	Diazinon 50 W	1.1–1.75 kg	0.45–0.7 kg	1	
		Diazinon 500 E	1.1–1.7 L	0.45–0.69 L	1	
	naled	Dibrom	1.1 L	0.44 L	4	
CABBAGE LOOPER						
microbial (group 11)	*Bacillus thuringiensis*	Thuricide HPC	2.0–4.25 L	0.8–1.7 L	0	Most effective against small larvae.
		Dipel 2X DF	275–550 g	110–220 g	0	
		Biprotec CAF	1.4–2.8 L	0.56–1.12 L	0	

[1] Pre-Harvest Interval.

Chemical Fruit Ripening

Ethephon (Ethrel) is used on processing tomatoes to trigger uniform ripening for once-over harvest. It will also enhance ripening in the late cultivars or during late seasons. For best results, apply ethephon to healthy fields. If plants are under moisture or disease stress, avoid use of ethephon or apply it at reduced rates.

Ethephon is only effective on mature green fruit. Mature green fruit contain a gelatinous pulp surrounding the seeds. Time applications for when 5%–20% of the fruit are showing red colour development.

Good spray coverage on fruit and foliage is essential for maximum effectiveness. Use the higher label rates when day temperatures are below 18°C (64°F) or when plant growth is dense. Excessive rates of ethephon will cause defoliation, reduce fruit quality and shorten field holding ability. Cool temperatures will delay colour development and extend the duration between treatment and harvest. Generally, fruit is ready to harvest 14–21 days after treatment.

Ethrel is not recommended for use on fresh-market tomatoes.

Harvest and Storage

Mature-green fresh-market tomatoes may be stored at 13°C–21°C (55°F–70°F) for 1–3 weeks. Firm, ripe tomatoes should be stored at 8°C–10°C (46°F–50°F) for no more than 4–7 days. Maintain storage at a relative humidity of 90%–95%.

For more information, see Chapter 6, *Food Safety and Storage*, on page 45.

A cover crop should be seeded after harvest is completed; this will protect soil and reduce erosion. In addition, the cover crop will absorb and tie up left-over nitrogen fertilizer and reduce leaching.

10. Precautions with Pesticides

Read the product label before using a pesticide!

Review the Grower Pesticide Safety Course Manual.

Keep detailed spray records.

Pesticide Regulations

Before a pesticide can be sold or used in Canada, it must be registered under the federal *Pest Control Products Act* (PCP Act). The PCP Act registration number on the front panel of the label identifies the pesticide and tells you that the pesticide is registered and can be legally used in Canada. It is an indication that the Pest Management Regulatory Agency (PMRA) completed its scientific review of this pest control product and found that the product has value and that the potential hazards to the environment and human health were assessed and found acceptable when following the label directions.

The pesticide label is a legal document. It tells you how the pesticide can be legally used. Off-label use is illegal. It is against the law to use the pesticide in any other way or on any other crop or pest. Labels for all registered pesticides are on the PMRA website: www.pmra-arla.gc.ca.

For more information about pesticide regulations, see:

- Inside front cover of this publication
- PMRA website: www.pmra-arla.gc.ca
- PMRA Pest Management Information Service: 1-800-267-6315 (within Canada) or 1-613-736-3799 (outside of Canada)
- Ontario Ministry of the Environment (MOE) website: www.ene.gov.on.ca
- Your regional MOE Pesticides Specialist. See Appendix B, *Ontario Ministry of Environment — Regional Offices Contact Information*, on page 228.

Pesticide Application Information

Read the pesticide label thoroughly before application. The label provides important information, such as:

- directions of use (rates of application, crops it can be used on, target pests, crop rotation restrictions, total number of applications)
- personal protective equipment that should be worn
- health hazards and toxicity
- re-entry intervals
- buffer zones
- special warnings
- steps to be taken, in case of an accident
- disposal

For more information on hazards, check the Material Safety Data Sheet (MSDS) or contact the manufacturer. Another resource for pesticide application information is the Ontario Pesticide Education Program's Grower Pesticide Safety Course Manual.

Re-Entry Intervals

The re-entry interval, also referred to as **Restricted Entry Interval (REI)**, is the period of time following a pesticide application during which workers must not enter the treatment area without wearing protective clothing and personal protective equipment. This allows any pesticide residue and vapours to dissipate from the field, preventing the possibility of inadvertent pesticide poisoning.

Health Canada reviews each pesticide to determine whether the label should include a specific re-entry interval. If no re-entry interval is stated on the label, assume that the spray solution must be dry before re-entry can occur. Some pesticides have labels that carry a warning about working in treated crops. Follow the label recommendations. See Table 11–3, *Re-entry Intervals for Pesticides Used on Vegetable Crops*, on page 222.

Days To Harvest (preharvest intervals, pregrazing and feeding intervals)

These intervals state the minimum time that must pass between the last pesticide application and the harvesting of the crop, or the grazing or cutting of the crop for livestock feed. If you harvest a crop before the preharvest interval (PHI) has passed, there may be pesticide residues in excess of the Maximum Residue Limits (MRL) set by Health Canada. The preharvest intervals for each product and crop are included in the pesticide recommendation tables in Chapter 9, starting on page 67.

To avoid exceeding the Maximum Residue Limits, always follow the directions on the label.

Protect the Environment

Protect Water Sources

Mix pesticides and load the sprayer away from any water supply, including wells, ponds or streams.

Clean your spray equipment away from wells, ponds, streams and ditches. Apply the diluted rinse water to the treatment area (crop).

Use an anti-backflow device to prevent back-siphoning if you must take water from wells, ponds, streams or other sources.

Sweep granular pesticides off driveways and hard surfaces, back onto the treated area, to prevent them from contaminating water sources.

Setback Distances for Water Bodies

It is an offence under the federal *Fisheries Act* to introduce any material into water that may be harmful to fish or fish habitat. To protect these waters, applicators must determine a suitable setback distance between the area to be protected and the area where pesticide treatments are planned. The protected area includes the water body as well as adjacent riparian (riverbank) areas that contribute to fish food and habitat.

Prevent Bee Poisoning

It is important to protect bees when you spray. Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops also offer bees important sources of nectar for honey production.

Most organophosphate and carbamate insecticides are highly toxic to bees. Read each pesticide label for specific precautions regarding bees.

Manage Drift

- Do not spray when wind speeds are high or gusty.
- Read the product label for information regarding buffer zones, sprayer output (water volume) and recommended nozzles.
- Use the recommended sprayer output (L/ha).
- Use the most appropriate nozzle for the type of application. Where practical, use air induction/venturi nozzles. These nozzles significantly reduce drift when compared to conventional nozzles.
- Check the height of the boom to the target. Minimize the distance as much as possible.
- Do not apply pesticides if the wind is blowing towards susceptible crops or environmentally sensitive areas such as watercourses.
- Use spray plume protection where practical or available (hoods, shrouds, screens and air curtains).
- Use drift-reducing adjuvants in the spray tank as directed by the label.
- Use wick weeders, instead of spraying, when possible.
- Use non-volatile pesticides.

For more information about spray drift, see:

- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices — Pesticide Storage, Handling and Application,* Order No. BMP13.
- Ontario Pesticide Education Program (Ridgetown College) videos *How to Manage Spray Drift* and *Spray Drift Reduction Through Air Induction,* available at www.opep.ca/Educational/EducationalMaterials.htm.

Buffer Zones

Leave a suitable **buffer zone** between the treatment area and adjacent sensitive areas. Buffer zones are areas left untreated to protect an adjacent sensitive area, aquatic system or natural habitat.

Adjacent sensitive areas include cultivated plants grown for human consumption, plants sensitive to herbicide drift, trees or shrubs that may be damaged by herbicides leaching to roots, and areas where children play.

Aquatic systems include lakes, reservoirs, streams, creeks, ditches, marshes, wetlands, ponds, well heads, commercial fish ponds, etc.

Natural habitats include hedgerows, grasslands, shelterbelts, windbreaks, woodlots, vegetative strips, etc.

Some pesticide labels specify buffer zones requirements.

Pesticide Disposal

Empty Pesticide Containers

Never reuse empty containers.

The **Ontario Pesticide Container Recycling Program** is available to growers and commercial applicators. Through this program, **clean, triple rinsed, plastic/metal pesticide containers** (up to 23 L for plastic and 20 L for metal) can be returned to Pesticide Container Depots located throughout the province. To locate the Pesticide Container Recycling Depot closest to you, call the Ontario Pesticide Education Program at **1-800-652-8573.**

Surplus Spray Mix

The best way to dispose of any excess spray mix is to find other fields that require an application of this pesticide. Before spraying, check the label to make sure the pesticide is registered for use on that crop.

If you cannot find another field to spray, dilute the remaining spray mix by adding **10 parts of water for each 1 part of spray mix.** This diluted solution can be safely applied to the treated area as long as you do not exceed the pesticide rate recommended on the label. Be sure to check the label for any restrictions about crop rotation, days to harvest or surplus spray mix disposal.

NEVER re-spray the treated field with undiluted spray mix. Spraying an area twice will double the recommended pesticide rate. This may cause illegal pesticide residues in the harvested crop or harmful residues in the soil that can cause crop damage.

Surplus Pesticides in Storage

If you have pesticides that you do not need or cannot use, be sure to dispose of them safely.

Contact the supplier. It is sometimes possible to return unused pesticide if it is still in its original container.

If you cannot find any way to use the product as shown on the label, then you must dispose of the waste using waste haulers licensed under Part V of the *Environmental Protection Act* to carry hazardous wastes. Look in the Yellow Pages of your telephone directory under "Liquid Waste Removal." Watch your local paper for "Obsolete Pesticide Collection Days."

Storing Pesticides

Ontario's *Pesticides Act* and Regulation 914 give storage requirements for storage facilities. The storage requirements that must be followed depend on which schedules of pesticides that you store.

For more information about storing pesticides, see:

- OMAFRA Factsheet, *Pesticide Handling Facility,* Order No. 94-037
- Ontario Pesticide Education Program (Ridgetown College) Grower Pesticide Safety Course Manual, available at www.opep.ca/Educational/EducationalMaterials.htm

Pesticide Spills

If a pesticide spill causes, or is likely to cause, an adverse effect, you must notify the Ministry of the Environment Spills Action Centre at 1-800-268-6060 (24 hr a day, 7 days a week) and your municipality (Regulation 914, s. 29).

Protect yourself before beginning to clean up any spill. Clean up spills immediately.

In the case of **minor spills:**

- For liquids, cover the spill with a thick layer of absorbent material such as kitty litter, vermiculite or dry soil. Sweep or shovel the material into a waste drum.
- For powders and granular, sweep or shovel the material into a waste drum.

In the case of a **major spill:**

- Remove any people or animals from the spill area. Stop the spill from spreading. Do not let the pesticide enter any watercourse.

For information on preventing spills, see the OMAFRA Factsheet, *Ways to Avoid Pesticide Spills,* Order No. 96-025.

Emergency Procedures for Pesticide Poisoning and First Aid Information

See inside back cover.

11. Pesticides Used on Vegetable Crops in Ontario

Table 11–1. Pesticides Used on Vegetable Crops in Ontario

Examples of Brand Name/ Trade Name[1]	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule[2]	Crop Recommended Registrations	Company of Agent's Code
1,3 dichlorpropene	*See TELONE II*					
1,3 dichlorpropene + chloropicrin	*See TELONE C-17*					
abamectin	*See AGRI-MEK*					
acephate	*See ORTHENE*					
acetamiprid	*See ASSAIL*					
ACROBAT 50 WP	dimethomorph	f	50	2	potatoes	ENG
ACTARA 240SC	thiamethoxam	i	240 g/L	2	potatoes	SYZ
ACTARA 25 WG	thiamethoxam	i	25	2	potatoes	SYZ
ACTIVOL	gibberellic acid	pgr	0.92 g/tablet	6	rhubarb	NOC
ADMIRE 240 F	imidacloprid	i	240 g/L	3	brassica crops, cucurbits (vine crops) eggplant, lettuce, potatoes, sweet potatoes tomatoes	BCZ
ADMIRE 240 SPT	imidacloprid	i	240 g/L	3	potato seed piece	BCZ
AGRI-MEK 1.9% EC	abamectin	i	19 g/L	2	celery	SYZ
AGROX B-2	diazinon + captan	s	11 + 33.5	2	beans, peas, sweet corn	NOC
AGROX CD	diazinon + captan	s	15 + 15	2	beans, peas, sweet corn	NOC
ALIAS 240 EC	imidacloprid	i	240 g/L	3	lettuce (field), potatoes, tomatoes	UAG
ALIETTE WDG	fosetyl-al	f	80	2	lettuce, onions, broccoli, bok choy	BCZ
ALLEGIANCE FL	metalaxyl	s	317 g/L	2	beans, peas, sugarbeets, sweet corn	BCZ
ALLEGRO 500 F	fluazinam	f	40	2	potato	ISK
APRON FL	metalaxyl	s	317 g/L	2	beans, peas, sugarbeets, sweet corn	BCZ
APRON MAXX RTA	metalaxyl-m + fludioxonil	s	1.1 + 0.73	2	beans, peas	SYZ
APRON XL LS	metalaxyl-M	s	33.3	2	beans, beets (table), carrots, cucurbits (vine crops), leafy greens, lettuce, onions, peas, spinach, sugarbeets , sweet corn	SYZ
ASSAIL 70 WP	acetamiprid	i	70	3	brassica crops, celery, lettuce, endive, parsley, spinach, swiss chard, leafy greens (see label), peppers, potatoes, rhubarb, tomatoes	DUQ
azoxystrobin	*See QUADRIS, DYNASTY*					
Bacillus subtilis	*See SERENADE*					
Bacillus thuringiensis	*See NOVODOR, DIPEL, THURICIDE, BIOPROTEC*					
BASAMID GRANULAR	dazomet	n	97	2	non-crop areas	BAZ
BIOPROTEC CAF	*Bacillus thuringiensis*	i	11,400 IU/ mg	2	beans (snap), brassica crops, herbs, sweet corn, tomatoes	AFG
BOTRAN 75 W	dichloran	f	75	3	beans, garlic, lettuce	GOW

Use Codes

a – acaricide
i – insecticide
r – rodenticide
b – bactericide
m – miticide
s – seed treatment
f – fungicide
n – nematicide
v – vine killing
h – herbicide
pgr – plant growth regulator

Table 11–1. Pesticides Used on Vegetable Crops in Ontario (continued)

Examples of Brand Name/ Trade Name[1]	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule[2]	Crop Recommended Registrations	Company of Agent's Code
boscalid	*See LANCE*					
BRAVO 500	chlorothalonil	f	500 g/L	3	asparagus, broccoli, Brussels sprouts, cabbage, cauliflower, carrots, celery, cucurbits (vine crops), onions, parsnips, potatoes, sweet corn, tomatoes	SYZ
BUMPER 418 EC	propiconazole	f	418 g/L	2	sweet corn	UAG
BUSAN 1020	metam sodium	n	33	3	non-crop areas	BUL
CABRIO EG	pyraclostrobin	f	20	3	beets (table), carrots, cucurbits (vine crops), eggplant, garlic, horseradish, onions, peppers, radish, rutabaga, tomatoes	BAZ
captan	*See CAPTAN, MAESTRO, SUPRA CAPTAN*					
CAPTAN FL	captan	s	30	2	beans, peas, sweet corn	NOC
carbaryl	*See SEVIN XLR*					
carbathiin-thiram	*See PRO-GRO, VITAFLO*					
carbofuran	*See FURADAN*					
chlorothalonil	*See BRAVO*					
CHLOROPICRIN 100	chloropicrin	n	99	5	peppers, potatoes, tomatoes	HND
chlorpyrifos	*See LORSBAN, PYRIFOS, PYRINEX*					
CITATION 75WP	cyromazine	i	75	2	brassica leafy greens (see label) celery, lettuce, leafy greens (see label), parsley, spinach, swiss chard	SYZ
clothianadin	*See PONCHO*					
COPPER 53 W	copper sulfate	f	53	2	beets (table), broccoli, Brussels sprouts, cabbage, cauliflower, celery, cucurbits (vine crops), potatoes.	UAG
copper hydroxide	*See PARASOL, KOCIDE*					
copper oxychloride	*See COPPER SPRAY*					
COPPER SPRAY	copper oxychloride	f	50	3	celery, cucurbits (vine crops), potatoes	UAG
copper sulfate	*See COPPER 53W*					
COUNTER 15 G	terbufos	i	15	5	sugarbeets	BAZ
CRUISER 5FS	thiamethoxam	s	47.6	2	beans, peas, sweet corn	SYZ
CURZATE 60 DF	cymoxanil	f	60	2	potatoes	DUQ
cyazofamid	*See RANMAN*					
CYGON 480	dimethoate	i	480 g/L	2	asparagus, beans, beets (table), broccoli, Brussels sprouts, cauliflower, Chinese broccoli, Chinese cabbage, pak choy, eggplant, lettuce, peas, peppers, potatoes, swiss chard, tomatoes	BAT, CAU
cyhalothrin-lambda	*See MATADOR*					
cymoxanil	*See CURZATE*					
cypermethrin	*See RIPCORD*					
cyprodinil + fludioxonil	*See SWITCH*					
cyromazine	*See GOVERNOR, CITATION*					
dazomet	*See BASAMID*					
DCT	diazinon + captan + thiophanate-methyl	s	6 + 18 + 14	3	sweet corn	NOC

Use Codes

a – acaricide
i – insecticide
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n – nematicide
v – vine killing
h – herbicide
pgr – plant growth regulator

Table 11–1. Pesticides Used on Vegetable Crops in Ontario (continued)

Examples of Brand Name/ Trade Name[1]	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule[2]	Crop Recommended Registrations	Company of Agent's Code
DECIS 5 EC	deltamethrin	i	50 g/L	2	asparagus, broccoli, Brussels sprouts, cabbage, cauliflower, kale, onions, peppers, potatoes, sweet corn, tomatoes	BCZ
DECREE 50 WDG	fenhexamid	f	50	2	tomato transplants (greenhouse)	TOA
deltamethrin	*See DECIS*					
DES-I-CATE	endothall	v	62 g/L	2	potatoes	CRA
diazinon	*See DIAZINON*					
diazinon + captan	*See AGROX*					
diazinon + captan + thiophanate-methyl	*See DCT*					
DIAZINON 50 W	diazinon	i	50	2	carrots, onions, parsnips, peppers, radishes, spinach, swiss chard, tomatoes	UAG
DIAZINON 500 E	diazinon	i	500 g/L	2	beets (table), lettuce, onions, parlsey, parsnips, radishes, spinach, swiss chard, tomatoes	UAG
DIBROM	naled	i	864 g/L	2	beans (lima), broccoli, Brussels sprouts, cabbage, cauliflower, kale, mustard greens, celery, lettuce, endive, onions, peas, potatoes, spinach, sugarbeets, tomatoes	UAG
dichloran	*See BOTRAN*					
dicofol	*See KELTHANE*					
difenoconazole + methalaxyl-M	*See DIVIDEND*					
dimethoate	*See CYGON, LAGON*					
dimethomorph	*See ACROBAT*					
DIPEL 2X DF	*Bacillus thuringiensis*	i	32,000/mg	3	brassica crops, herbs, lettuce, parsley, spinach, sweet corn, tomatoes	VAN
diquat	*See REGLONE*					
DITHANE DG	mancozeb	f	75	3	carrots, celery, cucurbits (vine crops), dry onions, potatoes, tomatoes	DWE
DITHANE F-45	mancozeb	f	37	3	seed potatoes (post harvest)	DWE
DIVIDEND XL RTA	difenoconazole + metalaxyl-m	s	3.37 + 0.27	2	sweet corn	SYZ
DYNASTY 100 FS	azoxystrobin	s	100 g/L	2	sweet corn	SYZ
endosulfan	*See THIODAN, THIONEX*					
endothall	*See DES-I-CATE*					
ENTRUST 80W	spinsoad	i	80	2	beans, brassica crops, eggplant, lettuce, endive, leafy greens, peppers, potatoes, radishes, rhubarb, rutabagas, turnips, spinach, swiss chard, sweet corn, tomatoes	DWE
famoxadone + cymoxanil	*See TANOS*					
fenamidone	*See REASON*					
fenhexamid	*See DECREE*					
FERBAM 76 WDG	ferbam	f	76	3	transplant lettuce	UAG
ferric phosphate	*See SLUGGO*					
fluazinam	*See ALLEGRO*					
fludioxonil	*See MAXIM*					

Use Codes

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h – herbicide
pgr – plant growth regulator

Table 11–1. Pesticides Used on Vegetable Crops in Ontario (continued)

Examples of Brand Name/ Trade Name[1]	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule[2]	Crop Recommended Registrations	Company of Agent's Code
fludioxonil + metalaxyl-m	*See MAXIM XL*					
FORCE 3.0 G	tefluthrin	i	3	2	sweet corn	SYZ
fosetyl-al	*See ALIETTE*					
FULFILL 50 WG	pymetrozine	i	50	2	potatoes	SYZ
FURADAN 480 F	carbofuran	i	480 g/L	5	peppers, potatoes, sweet corn	BCZ
GAUCHO 480 FL	imidacloprid	s	480 g/L	3	sweet corn	BCZ
GAVEL 75 DF	zoxamide + mancozeb	f	8.4 + 66.7	3	potatoes	DWE
gibberellic acid	*See ACTIVOL*					
glufosinate ammonium	*See IGNITE*					
GOVERNOR 75 WP	cyromazine	s	75	5	imported onion seed	SYZ
HEADLINE EC	pyraclostrobin	f	250 g/L	2	beans, peas, potatoes, sugarbeets, sweet corn	BAZ
hydrogen peroxide	*See STOROX*					
IGNITE 15 SN	glufosinate ammonium	v	150 g/L	3	potatoes	BCZ
imidacloprid	*See ADMIRE, GAUCHO, ALIAS*					
IMIDAN 50 WP	phosmet	i	50	3	carrots, celery	GOW
iprodione	*See ROVRAL*					
kaolin clay	*See SURROUND*					
KELTHANE 50 W	dicofol	m	51	2	beans, cucurbits (vine crops)	DWE
KOCIDE 2000	copper hydroxide	f	61.4	2	peppers (field and transplants), potatoes, tomatoes (field and transplants)	DUQ
LAGON 480	dimethoate	i	480 g/L	2	asparagus, beans, broccoli, Brussels sprouts, cauliflower, kale, Chinese broccoli, eggplant, lettuce, peas, peppers, potatoes, swiss chard, tomatoes	UAG
LANCE WDG	boscalid	f	70	5	beans (snap and lima), carrots, cucurbits (vine crops) eggplant, lettuce, onions, peas, peppers, potatoes, tomatoes	BAZ
LANNATE TNG	methomyl	i	90	5	beans, broccoli, Brussels sprouts, cabbage, cauliflower, head lettuce, peas, sweet corn, tomatoes	DUQ
LORSBAN 15G	chlorpyrifos	i	15	3	broccoli, Brussels sprouts, cabbage, cauliflower, onions, rutabaga	DWE
LORSBAN 4E	chlorpyrifos	i	480 g/L	2	carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, Chinese cabbage, pak choy, cucumber, garlic, onions (dry), radishes, peppers, potatoes, rutabagas, sugarbeets, sweet corn	DWE
LORSBAN 50W	chlorpyrifos	i	50	2	cabbage	DWE
MAESTRO 80 DF	captan	f	80	2	cucumber, tomatoes, vegetable transplants in greenhouse (crucifer, eggplant, pepper, tomatoes, celery)	TOA
MALATHION 25W	malathion	i	25	3	asparagus, beets (table), cucurbits (vine crops), peas, spinach, tomatoes	UAG

Use Codes

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h – herbicide
pgr – plant growth regulator

Table 11–1. Pesticides Used on Vegetable Crops in Ontario (continued)

Examples of Brand Name/ Trade Name[1]	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule[2]	Crop Recommended Registrations	Company of Agent's Code
MALATHION 500 E	malathion	i	500 g/L	3	asparagus, beans, beets (table), celery, cucurbits (vine crops), garlic, lettuce, peas, peppers, radishes, sugarbeets, tomatoes	UAG
maleic hydrazide	*See ROYAL MH 60*					
mancozeb	*See DITHANE, TUBERSEAL, POTATO ST, PENNCOZEB, MANZATE PRO-STICK*					
MANZATE PRO-STICK	mancozeb	f	75	2	carrots, celery, cucurbits (vine crops), onions (dry), potatoes, sugarbeets, tomatoes	DUQ
MATADOR 120 EC	cyhalothrin-lambda	i	120 g/L	5	asparagus, beans, broccoli, Brussels sprouts, cabbage, cauliflower, garlic, lettuce (head), onions, peas, potatoes, sweet corn, sweet potatoes, tomatoes	SYZ
MAXIM 480 FS	fludioxonil	s	40.3	2	sweet corn	SYZ
MAXIM PSP	fludioxonil	s	0.5	2	potato seed piece	SYZ
MAXIM XL	fludioxonil + metalaxyl-m	s	21 + 8.4	2	sweet corn	SYZ
metalaxyl	*See RIDOMIL, APRON, ALLEGIANCE*					
metalaxyl-M	*See RIDOMIL GOLD, APRON XL LS*					
metalaxyl-M + chlorothalonil	*See RIDOMIL GOLD + BRAVO*					
metalaxyl-m + mancozeb	*See RIDOMIL GOLD MZ*					
metalaxyl-m + fludioxonil	*See APRON MAXX*					
metam sodium	*See BUSAN, VAPAM*					
methamidophos	*See MONITOR*					
methomyl	*See LANNATE TNG*					
metiram	*See POLYRAM*					
MICROSCOPIC SULPHUR	sulphur	f	92	6	rutabagas	UAG
MILSTOP	potassium bicarbonate	f	85	3	cucurbits (vine crops), peppers	BWI
mineral oil	*See SUPERIOR OIL*					
MISSION 418 EC	propiconazole	f	418 g/L	2	asparagus, rutabagas	UAP
MONITOR 480	methamidophos	i	480 g/L	5	broccoli, Brussels sprouts, cabbage, cauliflower, head lettuce, potatoes	TOA/ BCZ
myclobutanil	*See NOVA*					
naled	*See DIBROM*					
NO-DAMP	oxine benzoate	f	3.2	3	vegetable seedlings in greenhouse	PLG
NOVA 40W	myclobutanil	f	40	2	asparagus	DWE
novaluron	*See RIMON*					
NOVODOR	*Bacillus thuringiensis*	i	18,000/g	3	potatoes, tomatoes	VAN
ORTHENE 75 SP	acephate	i	75	2	celery, Brussels sprouts, cabbage, cauliflower, head lettuce, peppers, potatoes, sweet corn, tomatoes	TOA
oxamyl	*See VYDATE*					
oxine benzoate	*See NO-DAMP*					
PARASOL FLOWABLE	copper hydroxide	f	24.4	3	beans, cucumbers, peppers, potatoes, tomatoes	NUA
PARASOL WP	copper hydroxide	f	50	2	sugarbeets	NUA
PENNCOZEB 80 WP	mancozeb	f	80	3	carrots, celery, cucurbits (vine crops), onions (dry), potatoes, sugarbeets, tomatoes	ISK

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Table 11–1. Pesticides Used on Vegetable Crops in Ontario (continued)

Examples of Brand Name/ Trade Name[1]	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule[2]	Crop Recommended Registrations	Company of Agent's Code
permethrin	*See POUNCE*					
phosmet	*See IMIDAN*					
pirimicarb	*See PIRIMOR*					
PIRIMOR 50 DF	pirimicarb	i	50	2	asparagus, celery, lettuce, peas, peppers, potatoes, spinach, sweet corn	SYZ
POLYRAM 16 D	metiram	s	16	3	potato (seed piece)	BAZ
POLYRAM DF	metiram	f	80	3	asparagus, carrots, celery, potatoes, sugarbeets, tomatoes	BAZ
PONCHO 600	clothianadin	s	48	5	sweet corn	BCZ
POTATO ST16	mancozeb	s	16	3	potato (seed piece)	UAG
potassium bicarbonate	*See MILSTOP*					
POUNCE 384 EC	permethrin	i	384 g/L	3	asparagus, beans, beets (table) carrots, broccoli, Brussels sprouts, cabbage, cauliflower, pak choy, Chinese cabbage, horseradish, lettuce, onions, peas, peppers, potatoes, radishes, rutabagas, sweet corn, tomatoes	UAG/ BCZ
PRISTINE WG	pyraclostrobin + boscalid	f	25.2 + 12.8	5	carrots, garlic, onions, leeks, shallots	ENG
PRO-GRO	carbathiin + thiram	s	30 + 50	3	onions	CRE
propamocarb + chlorothalonil	*See TATTOO C*					
propiconazole	*See BUMPER, MISSION, TOPAS, TILT*					
pyraclostrobin	*See CABRIO, HEADLINE*					
pyraclostrobin + boscalid	*See PRISTINE*					
PYRIFOS 15G	chlorpyrifos	i	15	3	broccoli, Brussels sprouts, cabbage, cauliflower, onions	UAG
pyrimethanil	*See SCALA*					
PYRINEX 480 EC	chlorpyrifos	i	480 g/L	2	carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, Chinese broccoli, Asian radish, cucumbers, garlic, onions (dry), peppers, potatoes, radish, rutabaga, sweet corn	UAG
pyrmetrozine	*See FULFILL*					
QUADRIS FLOWABLE	azoxystrobin	f	250 g/L	2	beets (table), carrots, horseradish, potatoes, radishes, rutabagas/turnips, spinach, sugarbeets, sweet corn, tomatoes	SYZ
QUINTOZENE 75 WP	quintozene	f	75	3	broccoli, Brussels sprouts, cabbage, cauliflower	PLG
RANMAN 400 SC	cyazofamid	f	34.5	3	potatoes, cucurbits (vine crops)	ISK
REASON 500 SC	fenamidone	f	500 g/L	2	potatoes	BCZ
REGLONE	diquat	v	240 g/L	3	potatoes	SYZ
RIDOMIL GOLD 1G	metalaxyl	f	2	2	carrots, lettuce	SYZ
RIDOMIL GOLD 480 SL	metalaxyl-M	f	480 g/L	2	snap bean, potatoes	SYZ
RIDOMIL GOLD MZ 68 WP	metalaxyl-M + mancozeb	f	4 + 64	2	lettuce (head), onions, potatoes	SYZ
RIDOMIL GOLD + BRAVO twin pak	metalaxyl-M + chlorothalonil	f	480 + 500 g/L	2	potatoes	SYZ
RIMON 10 EC	novaluron	i	10	5	potatoes	UAG

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Table 11–1. Pesticides Used on Vegetable Crops in Ontario (continued)

Examples of Brand Name/ Trade Name[1]	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule[2]	Crop Recommended Registrations	Company of Agent's Code
RIPCORD 400 EC	cypermethrin	i	407 g/L	2	asparagus, carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, lettuce, onions, potatoes, rutabagas, sweet corn, tomatoes	BAZ
RONILAN EG	vinclozolin	f	50	3	beans, lettuce	BAZ
ROVRAL	iprodione	f	50 g/kg	3	beans, cabbage, cauliflower, garlic, leeks, lettuce, onions, carrots (imported seed)	BCZ
ROYAL MH 60 SG	maleic hydrazide	pgr	60	3	dry onions, potatoes	CRE
SCALA 400 SC	pyrimethanil	f	480 g/L	5	potatoes	BCZ
SENATOR 70WP	thiophanate-methyl	f	70	3	sugarbeets	ENG
SENATOR PSPT	thiophanate-methyl	s	10	6	potatoes (seed piece)	ENG
SEVIN XLR	carbaryl	i	480 g/L	3	asparagus, beans, brassica crops, carrots, celery, cucurbits (vine crops), eggplant, lettuce, leafy greens, peppers, radishes, rutabagas, sweet corn, tomatoes	BCZ
SERENADE MAX	*Bacillus subtilis*	f	14.6	3	celery, garlic, lettuce, onions	UAG
SLUGGO	ferric phosphate	i	0.76	6	beans, brassica crops, peas, sweet corn	ENG
spinosad	*See SUCCESS, ENTRUST*					
STOROX	hydrogen peroxide	f	27	5	potatoes, sweet potatoes	BIB
SUCCESS 480 SC	spinosad	i	480 g/L	3	beans (snap), brassica crops, celery, eggplant, lettuce, leafy greens, peppers, potatoes, radishes, rhubarb, rutbagas, spinach, swiss chard, sweet corn, tomatoes	DWE
sulphur	*See MICROSCOPIC SULPHUR*					
SUPERIOR OIL 70	mineral oil	a, i	99	6	rutabagas	***
SUPRA CAPTAN 80 WDG	captan	f	80	2	cucumbers, tomatoes, vegetable transplants in greenhouse (brassica crops, eggplant, peppers, tomatoes, celery)	UAG
SURROUND WP	kaolin clay	i	95	6	cucurbits (vine crops)	ENG
SWITCH 62.5 WG	cyprodinil + fludioxonil	f	37.5 + 25	2	mustard/turnip greens, cabbage, carrots, onions	ENG
TANOS 50 DF	famoxadone + cymoxanil	f	25 + 25	2	potatoes, tomatoes	DUQ
TATTOO C	propamocarb + chlorothalonil	f	375 g/L + 375 g/L	2	potatoes	BCZ
tefluthrin	*See FORCE*					
TELONE C-17	1,3 dichloropropene + chloropicrin	n,f	78 + 16.5	2	non-crop areas	DWE
TELONE II	1,3 dichloropropene	n	97.5	2	non-crop areas	DWE
terbufos	*See COUNTER*					
thiamethoxam	*See ACTARA, CRUISER*					
THIODAN 4 EC	endosulfan	i	400 g/L	2	beans, broccoli, Brussels sprouts, cabbage, cauliflower, celery, cucurbits (vine crops), eggplant, head lettuce, peas, peppers, potatoes, rutabagas, spinach, tomatoes	BCZ
THIODAN 50 WP	endosulfan	i	50	2	celery, broccoli, Brussels sprouts, cabbage, cauliflower, , cucurbits (vine crops), eggplant, peppers, potatoes,	BCZ

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Table 11–1. Pesticides Used on Vegetable Crops in Ontario (continued)

Examples of Brand Name/ Trade Name[1]	Active Ingredient/ Common Name	Use	Guaranteed % Active Unless Stated	Ontario Schedule[2]	Crop Recommended Registrations	Company of Agent's Code
THIONEX 50 WP	endosulfan	i	50	2	beans (snap), broccoli, Brussels sprouts, cabbage, cauliflower,celery, cucurbits (vine crops), eggplant, lettuce (head), peas, peppers, potatoes, rutabagas, spinach, tomatoes	UAG
thiophanate-methyl	*See SENATOR*					
THIRAM 75 WP	thiram	s	75	2	beans, beets (table), broccoli, Brussels sprouts, cabbage, cauliflower, cucurbits (vine crops), lettuce, onions, peas, peppers, radishes, rutabagas, spinach, sugarbeets, sweet corn, sweet potatoes	CRE
THURICIDE HPC	*Bacillus thuringiensis*	i	4,000/mg	3	celery, brassica crops, spinach, tomatoes	VAN
TILT 250 E	propiconazole	f	250 g/L	2	sweet corn	SYZ
TOPAS 250 E	propiconazole	f	250 g/L	2	asparagus, rutabagas	ENG
TUBERSEAL	mancozeb	s	16	3	potato seed piece	NOC
VAPAM	metam sodium	h, f	380 g/L	3	preplant site preparation	UAG
vinclozolin	*See RONILAN*					
VITAFLO 280	carbathiin + thiram	s	15.59 + 13.95	3	beans, peas	BCZ
VYDATE L	oxamyl	i	240 g/L	5	potatoes	DUQ
ZINEB 80 W	zineb	f	80	3	asparagus, carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, lettuce, onions	UAG
zoxamide/mancozeb	*See GAVEL*					

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[1] Mention of a brand or trade name in this table does not constitute a guarantee or warranty of the product by the Ontario Crop Protection Committee nor that these products are approved to the exclusion of comparable products. All trade names are capitalized.

[2] **Ontario Classification Schedule:**
Listed below are the schedules classified under the Pesticides Act. The majority of materials listed for vegetables are classified as Schedule 2 or 5. Consult your local pest control product supplier or, for more information, contact the Ministry of the Environment office nearest you.

Schedule 1: Restricted. Use permit only.
Schedule 2: Restricted to certified agriculturists, licensed exterminators, registered custom sprayer and permit holders.
Schedule 3: Agriculturists and consumer use.
Schedule 4: Domestic products only.
Schedule 5: Limited to application on agricultural land. Similar to Schedule 2.
Schedule 6: Similar to Schedule 4 but may be registered for agricultural/commercial use, container size 1 L or greater.

Table 11–2.
Pest Control Product Companies

Code	Company/Agent	Website	Contact Number
****	Various manufacturers		
AFG	AEF Global Inc.	www.aefglobal.com	418-838-4441
BAT	Bartlett, N. M. Inc.	www.bartlett.ca	1-800-263-1287
BAZ	BASF Canada Inc.	www.agsolutions.ca	1-877-371-2273
BCZ	Bayer Crop Science	www.bayercropscience.ca	1-877-938-3737
BIB	BioSafe Systems	www.biosafesystems.com	1-888-273-3088
BUL	Buckman Labs of Canada		405-424-4404
BWI	BioWorks Inc	www.bioworksinc.com	1-800-877-9443
CAU	Cheminova Canada Inc	www.cheminova.com/	1-888-316-6260
CRA	Cerexagri	www.cerexagri.com/	1-800-438-6071
CRE	Chemtura Company	www.chemtura.com	519-669-1671
DUQ	Dupont Canada Inc.	www.dupont.ca/ag/	1-800-667-3925
DWE	Dow Agrosciences Canada Inc.	www.dowagro.ca	1-800-667-3852
ENG	Engage Agro Corp.	www.engageagro.com	866-613-3336
GOW	Gowan Company	www.gowanco.com/	1-800-883-1844
HND	Hendrix and Dail		831-637-0195
ISK	ISK BioSciences		440-357-4640
NOC	Norac Concepts Inc.	www.noracconcepts.com	519-821-3633
NUA	NuFarm Agriculture Inc.	www.nufarm.ca	1-888-252-2895
PLG	Plant Products Co. Ltd.	www.plantprod.com/	1-800-387-2449
SYZ	Syngenta Crop Protection	www.syngenta.ca/	1-877-214-5405
TOA	Arvesta Corp.	www.arvesta.com	919-678-4900
UAG	United Agri Products	www.uap.ca/	1-800-265-4624
VAN	Valent BioSciences Canada	www.valentbiosciences.com/	1-800-682-5368

Table 11–3.
Re-Entry Intervals for Pesticides Used on Vegetable Crops

Trade Name(s)	Active Ingredient	Re-Entry Interval	Recommended Crops
Admire 240F	imidacloprid	24 hr	brassica crops, cucurbits (vine crops) eggplant, lettuce, potatoes, sweet potatoes tomatoes
Alias 240 EC	imidacloprid	24 hr	lettuce (field), potatoes, tomatoes
Aliette WDG	fosetyl-al	12 hr	lettuce, onions, broccoli, bok choy
Allegro 500 F	fluazinam	24 hr	potato
Assail 70 WP	acetamiprid	12 hr	brassica crops, celery, lettuce, endive, parsley, spinach, swiss chard, leafy greens (see label), peppers, potatoes, rhubarb, tomatoes
Cabrio EG	pyraclostrobin	cucurbit crops: 24 hr potatoes: 48 hr root & bulb crops*: 72 hr (*hand-thinning activities)	beets (table), carrots, cucurbits (vine crops), eggplant, garlic, horseradish, onions, peppers, radish, rutabaga, tomatoes
Citation 75 WP	cyromazine	12 hr	brassica leafy greens (see label), celery, lettuce, leafy greens (see label), parsley, spinach, swiss chard
Curzate 60 DF	cymoxanil	24 hr	potatoes
Decree 50 WDG	fenhexamid	4 hr	tomato transplants (greenhouse)
Entrust 80W	spinosad	potatoes: 12 hr brassica crops*: 72 hr (*hand harvest or tying activities)	beans, brassica crops, eggplant, lettuce, endive, leafy greens, peppers, potatoes, radishes, rhubarb, rutabagas, turnips, spinach, swiss chard, sweet corn, tomatoes
Fulfill 50WG	pymetrozine	12 hr	potatoes
Furadan 480 F	carbofuran	48 hr	peppers, potatoes, sweet corn
Gavel 75 DF	zoxamide + mancozeb	48 hr	potatoes
Headline EC	pyraclostrobin	48 hr	beans, peas, potatoes, sugarbeets, sweet corn
Kocide 2000	copper hydroxide	greenhouse transplants: 24 hr	peppers, potatoes, tomatoes
Lance WDG	boscalid	4 hr	beans (snap and lima), carrots, cucurbits (vine crops) eggplant, lettuce, onions, peas, peppers, potatoes, tomatoes
Lannate TNG	methomyl	24 hr	beans, broccoli, Brussels sprouts, cabbage, cauliflower, head lettuce, peas, sweet corn, tomatoes
Lorsban	chlorpyrifos	24 hr cauliflower: 10 days	broccoli, Brussels sprouts, cabbage, cauliflower, Chinese cabbage, pak choy, carrots, celery, cucumber, garlic, onions (bulb), radishes, peppers, potatoes, rutabagas, sugarbeets, sweet corn
Maestro 80DF	captan	48 hr	cucumber, tomatoes, vegetable transplants in greenhouse (crucifer, eggplant, pepper, tomatoes, celery)
Matador 120 EC	cyhalothrin-lambda	24 hr	asparagus, beans, broccoli, Brussels sprouts, cabbage, cauliflower, garlic, lettuce (head), onions, peas, potatoes, sweet corn, sweet potatoes, tomatoes
Monitor 480	methamidophos	48 hr	broccoli, Brussels sprouts, cabbage, cauliflower, lettuce (head), potatoes
Pirimor 50 DF	pirimicarb	celery & spinach: 24 hr	asparagus, celery, lettuce, peas, peppers, potatoes, spinach, sweet corn
Pristine WG	pyraclostrobin + boscalid	3 day	carrots, onions, leeks, shallots
Pyrifos 15G,	chlorpyrifos	24 hr cauliflower: 10 days	broccoli, Brussels sprouts, cabbage, cauliflower, onions
Pyrinex 480 EC	chlorpyrifos	24 hr cauliflower: 10 days	carrots, celery, broccoli, Brussels sprouts, cabbage, cauliflower, Chinese broccoli, Asian radish, cucumbers, garlic, dry onions, peppers, potatoes, radish, rutabaga, sweet corn
Ranman 400 SC	cyazofamid	12 hr	potatoes, cucurbits (vine crops)
Ronilan EG	vinclozolin	lettuce: 12 hr	beans, lettuce

Table 11–3.
Re-Entry Intervals for Pesticides Used on Vegetable Crops (continued)

Trade Name(s)	Active Ingredient	Re-Entry Interval	Recommended Crops
Rovral	iprodione	12 hr	beans, cabbages, cauliflower, garlic, leeks, lettuce, dry onions
Success 480 SC	spinosad	potatoes: 12 hr brassica crops*: 72 hr (*hand harvest or tying activities)	beans (snap), brassica crops, celery, lettuce, leafy greens, peppers, potatoes, radishes, rhubarb, rutabagas, spinach, swiss chard, sweet corn, tomatoes
Supra Captan 80 WDG	captan	48 hr	cucumbers, tomatoes, vegetable transplants in greenhouse (brassica crops, eggplant, peppers, tomatoes, celery)
Tanos 50 DF	famoxadone + cymoxanil	24 hr	potatoes, tomatoes
Tattoo C	propamocarb + chlorothalonil	28 hr (4 hr for short term tasks)	potatoes
Telone C-17	1,3 dichloropropene + chloropicrin	72 hr	non-crop areas
Telone II	1,3 dichloropropene	72 hr	non-crop areas
Vydate L	oxamyl	24 hr	potatoes

Table 11–4.
Pesticides Used in Vegetable Crops That Affect Cholinesterase Levels in Blood

Product Name	Common Name(s)
acephate	Orthene 75 SP
carbaryl	Sevin XLR
carbofuran	Furadan 480 F
chlorpyrifos	Lorsban 50 W, Pyrifos 15 G, Pyrifos 50 W, Pyrinex 480 EC
diazinon	Diazinon 50 W, Diazinon 500 E, DZN 600 EW, Agrox B-2, Agrox CD
dimethoate	Cygon 480, Lagon 480 E
malathion	Malathion 25 W, Malathion 500 E
methamidophos	Monitor 480
methomyl	Lannate
naled	Dibrom
oxamyl	Vydate L
phosmet	Imidan 50 W
pirimicarb	Pirimor 50 WP
terbufos	Counter

12. Appendices

Appendix A.
Ontario Ministry of Agriculture, Food and Rural Affairs Crop Advisory Staff List

Specialty	Staff	Tel/Fax	E-mail
Brighton Resource Centre 95 Dundas St. E, RR#3 Brighton, ON K0K 1H0		Tel: 613-475-1630 Fax: 613-475-3835	
IPM Systems Specialist	Margaret Appleby	Tel: 613-475-5850	margaret.appleby@ontario.ca
Guelph OMAFRA 1 Stone Road West Guelph, ON N1G 4Y2			
Agroforestry Specialist	Todd Leuty	Tel: 519-826-3215	todd.leuty@ontario.ca
Crop Bioproducts Specialist	Mahendra Thimmanagari	Tel: 519-826-4593 Fax: 519-826-3567	mahendra.thimmanagari@ontario.ca
Crop Protection Program Lead	Denise Beaton	Tel: 519-826-6594 Fax: 519-826-4964	denise.beaton@ontario.ca
Director, Agriculture Development	Aileen MacNeil	Tel: 519-826-6588 Fax: 519-826-3567	aileen.macneil@ontario.ca
Manager, Field Crops	Brent Kennedy	Tel: 519-826-3257 Fax: 519-826-3567	brent.kennedy@ontario.ca
Manager, Greenhouse, Agroforestry and Specialty Crops	Annette Anderson	Tel: 519-826-3286 Fax: 519-826-3567	annette.anderson@ontario.ca
Manager, Horticulture Technology	Hugh Berges	Tel: 519-826-3288 Fax: 519-826-3567	hugh.berges@ontario.ca
Manager, Horticulture Crops	John Finlay	Tel: 519-826-6941 Fax: 519-826-3567	john.finlay@ontario.ca
Minor Use Coordinator	Jim Chaput	Tel: 519-826-3539 Fax: 519-826-4964	jim.chaput@ontario.ca
Organic Crop Production Program Lead	Hugh Martin	Tel: 519-826-4587 Fax: 519-826-4964	hugh.martin@ontario.ca
Potato Specialist	Eugenia Banks	Tel: 519-826-3678 Fax: 519-826-4964	eugenia.banks@ontario.ca
Product Development Specialist	Laurie Butter (Acting)	Tel: 519-826-4094 Fax: 519-826-3567	laurie.butter@ontario.ca
Vegetable Crops Specialist	Jennifer Allen	Tel: 519-826-4963 Fax: 519-826-4964	jennifer.allen@ontario.ca
Harrow **Greenhouse and Processing Crops Research Centre** 2585 County Road 20 Harrow, ON N0R 1G0		Tel: 519-738-2251 Fax: 519-738-4564	
Greenhouse Vegetable IPM Specialist	Gillian Ferguson	Tel: 519-738-1258	gillian.ferguson@ontario.ca
Greenhouse Vegetable Specialist	Shalin Khosla	Tel: 519-738-1257	shalin.khosla@ontario.ca
Weed Management – Horticulture Program Lead	Leslie Huffman	Tel: 519-738-1256	leslie.huffman@ontario.ca

Appendix A.
Ontario Ministry of Agriculture, Food and Rural Affairs Crop Advisory Staff List (continued)

Specialty	Staff	Tel/Fax	E-mail
Kemptville Resource Centre Box 2004, Concession Rd Kemptville, ON K0G 1J0		Tel: 613-258-8295 Fax: 613-258-8392	
Agroforestry Specialist	vacant	Tel: 613-258-8302	
Emerging Crops Specialist	Scott Banks	Tel: 613-258-8359	scott.banks@ontario.ca
Field Crops, IPM Program Lead – Bilingual	Gilles Quesnel	Tel: 613-258-8250	gilles.quesnel@ontario.ca
Lindsay Resource Centre 322 Kent St. W Lindsay, ON K9V 2Z9		Tel: 705-324-6125 Fax: 705-324-1638	
Forage Specialist	Joel Bagg	Tel: 705-324-5856	joel.bagg@ontario.ca
London Resource Centre 667 Exeter Road London, ON N6E 1L3		Tel: 519-873-4070 Fax: 519-873-4062	
Apple Specialist	John Gardner	Tel: 519-873-4084	john.gardner@ontario.ca
New Liskeard 280 Armstrong St., Box 4070 New Liskeard, ON P0J 1P0		Tel: 800-461-6132 Fax: 705-647-7993	
Agriculture and Rural Representative	Daniel Tassé	Tel: 705-647-2085	daniel.tasse@ontario.ca
Ridgetown Resource Centre Agronomy Building, Ridgetown College, Box 400, Main St. E. Ridgetown, ON N0P 2C0		Tel: 519-674-1690 Fax: 519-674-1564	
Entomologist – Field Crops Program Lead	Tracey Baute	Tel: 519-674-1696	tracey.baute@ontario.ca
Pathologist – Field Crops Program Lead	Albert Tenuta	Tel: 519-674-1617	albert.tenuta@ontario.ca
Soil Management Specialist – Field Crops	Adam Hayes	Tel: 519-674-1621	adam.hayes@ontario.ca
Soil Management Specialist – Hort Crops	Anne Verhallen	Tel: 519-674-1614	anne.verhallen@ontario.ca
Vegetable Crops Specialist	Janice LeBoeuf	Tel: 519-674-1699	janice.leboeuf@ontario.ca
Vegetable Crops Specialist	Elaine Roddy	Tel: 519-674-1616	elaine.roddy@ontario.ca
Simcoe Resource Centre P.O. Box 587, Blueline Rd & Hwy #3 Simcoe, ON N3Y 4N5		Tel: 519-426-7120 Fax: 519-428-1142	
Berry Crop Specialist	Pam Fisher	Tel: 519-426-2238	pam.fisher@ontario.ca
Fresh Market Quality Program Lead	Jennifer R. DeEll	Tel: 519-426-1408	jennifer.deell@ontario.ca
Ginseng and Medicinal Herbs Specialist	vacant	Tel: 519-426-4323	
IPM Specialist – Specialty Crops	Melanie Filotas	Tel: 519-426-4434	melanie.filotas@ontario.ca
New Crop Development Specialist	vacant	Tel: 519-426-4509	
Pome Fruit IPM Specialist	Kathryn Carter	Tel: 519-426-4322	kathryn.carter@ontario.ca
Transition Crop Specialist	Jim Todd	Tel: 519-426-3823	jim.todd@ontario.ca
Stratford Resource Centre 581 Huron St. Stratford, ON N5A 5T8		Tel: 519-271-0280 Fax: 519-273-5278	
Canola & Edible Beans Specialist	Brian Hall	Tel: 519-271-0083	brian.hall@ontario.ca
Cereals Specialist	Peter Johnson	Tel: 519-271-8180	peter.johnson@ontario.ca
Soil Fertility Specialist – Field Crops	Keith Reid	Tel: 519-271-9269	keith.reid@ontario.ca
Soybean Specialist	Horst Bohner	Tel: 519-271-5858	horst.bohner@ontario.ca

Appendix A.
Ontario Ministry of Agriculture, Food and Rural Affairs Crop Advisory Staff List (continued)

Specialty	Staff	Tel/Fax	E-mail
Vineland – HRIO, University of Guelph Box 7000, 4890 Victoria Ave. N Vineland Station, ON L0R 2E0		Tel: 905-562-4141 Fax: 905-562-3413	
Greenhouse Floriculture Specialist	Wayne Brown	Tel: 905-562-4141, ext. 179	wayne.brown@ontario.ca
Greenhouse Floriculture IPM Specialist	Graeme Murphy	Tel: 905-562-4141, ext. 106	graeme.murphy@ontario.ca
Vineland Resource Centre Adv. Serv. Building Box 8000, 4890 Victoria Ave. N Vineland Station, ON L0R 2E0		Tel: 905-562-4147 Fax: 905-562-5933	
Entomologist – Horticulture Program Lead	Hannah Fraser	Tel: 905-562-1674	hannah.fraser@ontario.ca
Nutrient Management Horticulture Crops Program Lead	Donna Speranzini	Tel: 905-562-1170	donna.speranzini@ontario.ca
Tender Fruit and Grape IPM Specialist	vacant	Tel: 905-562-1639	
Tender Fruit and Grape Specialist	Ken Slingerland	Tel: 905-562-1639	ken.slingerland@ontario.ca
Woodstock Resource Centre Box 666, Hwy. #59 N Woodstock, ON N4S 7Z5		Tel: 519-537-6621 Fax: 519-539-5351	
Nutrient Management Field Crops Program Lead	Christine Brown	Tel: 519-537-8305	christine.brown1@ontario.ca
University of Guelph 50 Stone Rd. E. Guelph, ON N1G 2W1		Tel: 519-824-4120	
Applied Research Coordinator – Field Crops *Crop Science Building*	Ian McDonald	Tel: 519-824-4120, ext.56707 Fax: 519-763-8933	ian.mcdonald@ontario.ca
Corn Industry Program Lead *Crop Science Building*	Greg Stewart	Tel: 519-824-4120, ext. 54865 Fax: 519-763-8933	greg.stewart1@ontario.ca
Nursery Crops Specialist *Edmund Bovey Building*	Jennifer Llewellyn	Tel: 519-824-4120, ext. 52671 Fax: 519-767-0755	jennifer.llewellyn@ontario.ca
Nutrition – Horticulture Program Lead Land Resource Science *Richards Building*	Christoph Kessel	Tel: 519-824-4120, ext. 52480 Fax: 519-824-5730	christoph.kessel@ontario.ca
Pathologist – Horticulture Program Lead *Edmund Bovey Building*	Michael Celetti	Tel: 519-824-4120, ext. 58910 Fax: 519-767-0755	michael.celetti@ontario.ca
Turfgrass Specialist *Guelph Turfgrass Institute* 328 Victoria Rd. S., R.R. # 2 Guelph, ON N1H 6H8	Pam Charbonneau	Tel: 519-824-4120, ext. 52597 Fax: 519-766-1704	pamela.charbonneau@ontario.ca
Weed Management Field Crops Program Lead *Crop Science Building, Room 303*	Mike Cowbrough	Tel: 519-824-4120, ext. 52580 Fax: 519-763-8933	mike.cowbrough@ontario.ca

Agricultural Information Contact Centre

Provides province-wide, toll-free technical and business information to commercial farms, agri-businesses and rural businesses.

1 Stone Rd. W.
Guelph, ON N1G 4Y2

Tel: 1-877-424-1300
Fax: 519-826-3442
E-mail: ag.info.omafra@ontario.ca

Guelph – ServiceOntario

1 Stone Rd. W.
Guelph, ON N1G 4Y2

Staff Directories — Phone 1-888-466-2372 or 519-826-3100

Appendix B.
Ontario Ministry of Environment —Regional Offices Contact Information

Region/County	Address	Telephone/fax
Central Region Toronto, Halton, Peel, York and Durham	5775 Yonge St., 8th Floor Toronto, Ontario M2M 4J1	Tel: 416-326-6700 Toll Free: 1-800-810-8048 Fax: 416-325-6347
West-Central Region Haldimand, Norfolk, Niagara, Hamilton-Wentworth, Dufferin, Wellington, Waterloo, Brant	119 King St. W., 12th Floor Hamilton, Ontario L8P 4Y7	Tel: 905-521-7640 Toll Free: 1-800-668-4557 Fax: 905-521-7820
Eastern Region Frontenac, Hastings, Lennox & Addington, Prince Edward, Leeds & Grenville, Prescott & Russell, Stormont/Dundas & Glengarry, Peterborough, Kawartha Lakes, Northumberland, Renfrew, Ottawa, Lanark, District of Nipissing (Twp. of South Algonquin), Haliburton	133 Dalton Ave. Kingston, Ontario K7L 4X6	Tel: 613-549-4000 Toll Free: 1-800-267-0974 Fax: 613-548-6908
Southwestern Region Elgin, Middlesex, Oxford, Essex, Kent, Lambton, Bruce, Grey, Huron, Perth, Muskoka, Simcoe	733 Exeter Rd. London, Ontario N6E 1L3	Tel: 519-873-5000 Toll Free: 1-800-265-7672 Fax: 519-873-5020
Northern Region (East) Manitoulin, Nipissing, Parry Sound, Sudbury, Algoma (East), Timiskaming, Sault Ste. Marie	199 Larch St., Ste. 1101 Sudbury, Ontario P3E 5P9	Tel: 705-564-3237 Toll Free: 1-800-890-8516 Fax: 705-564-4180
Northern Region (West) Algoma (West), Cochrane, Kenora, Rainy River, Timmins, Thunder Bay	435 James St. S., Ste. 331 Thunder Bay, Ontario P7E 6S7	Tel: 807-475-1205 Toll Free: 1-800-875-7772 Fax: 807-475-1745

Appendix C.
Accredited Soil-Testing Laboratories in Ontario

The following labs are accredited to perform soil tests for pH, buffer pH, P, K, Mg and Nitrate-N on Ontario soils.

Laboratory Name	Address	Telephone/Fax/E-mail	Contact
A & L Canada Laboratories Inc. Website: www.alcanada.com	2136 Jetstream Rd. London, Ontario N5V 3P5	Tel: 519-457-2575 Fax: 519-457-2664 E-mail: aginfo@alcanada.com	Mr. Greg Patterson Mr. Ian McLachlin
Accutest Laboratories Website: www.accutestlabs.com	146 Colonnade Rd. Unit #8 Nepean, Ontario K2E 7Y1	Tel: 613-727-5692 Fax: 613-727-5222 E-mail: phaulena@accutestlabs.com	Mrs. Lorna Wilson Mr. Peter Haulena
Agri-Food Laboratories Website: www.agtest.com	503 Imperial Rd. Unit #1 Guelph, Ontario N1H 6T9	Tel: 519-837-1600 1-800-265-7175 Fax: 519-837-1242 E-mail: lab@agtest.com	Mr. Dale Cowan
Brookside Laboratories, Inc. Website: www.blinc.com/	301 South Main St. New Knoxville, Ohio US 45871	Tel: 419-753-2448 Fax: 419-753-2949 E-mail: nfisher@blinc.com	Ms. Nicole Fisher Mr. Mark Flock
Soil and Nutrient Laboratory Website: www.labservices.uoguelph.ca/units/soil-nutrient/	University of Guelph P.O. Box 3650 95 Stone Rd. W. Guelph, Ontario N1H 8J7	Tel: 519-767-6226 Fax: 519-767-6240 E-mail: nschrier@lsd.uoguelph.ca	Mr. Nick Schrier
Stratford Agri Analysis Website: www.stratfordagri.com/	1131 Erie St. Box 760 Stratford, Ontario N5A 6W1	Tel: 519-273-4411 1-800-323-9089 Fax: 519-273-2163 E-mail: laboratory@daconutrition.com	Mr. Keith Lemp

There is no official accreditation in Ontario for tissue analysis, but all the accredited soil-testing labs are monitored for proficiency on tissue analyses.

Appendix D.
Vegetable Seed Suppliers

Wholesale Seed Companies (Sales to Dealers)

*Most sites include list of dealers

American Takii Inc.
www.takii.com
301 Natividad Rd.
Salinas, CA 93906 US
Phone: 831-443-4901 Fax: 831-443-3976

Crookham Co. Inc.
www.crookham.com
Box 520
Caldwell, ID 83606-0520 US
Phone: 208-459-7451 Fax: 208-454-2108
E-mail: ccoinfo@crookham.com

Hollar Seeds
(Cucurbit Seeds)
www.hollarseeds.com
Box 106
Rockyford, CO 81067 US
Phone: 719-254-7411 Fax: 719-254-3539

Norseco Seeds
Robert Dumolin
2914 Cure-Labelle Blvd.
Laval, QC H7P 5R9
Phone: 1-800-561-9693 Fax: 1-800-567-4594

Nunhems
www.nunhems.com/index.html
1200 Anderson Corner Rd.
Parma, ID 83660 US
Phone: 1-800-733-9505

Seminis (Asgrow, Peto Seeds, Royal Sluis, Hungnong)
www.seminis.com
Ron Garton
613 Tomahawk Cres.
Ancaster, ON L9G 3T4
Phone: 905-304-1795 Fax: 905-304-3820
E-mail: ron.garton@seminis.com

Syngenta Seeds – Rogers Brand
www.rogersadvantage.com
Bob Kotch
573 Gardener Rd.
Horseheads, NY 14845-1237 US
Phone: 607-739-0191
E-mail: bob.kotch@syngenta.com

Retail Seed Companies (Sales to Growers)

*Sales through sales reps, catalogue, website

Abbot & Cobb
www.acseed.com
Phone: 1-800-345-7333

August's Harvest Inc.
Warren Ham
32 Centre St.
Stratford, ON N5A 1E3
Phone: 519-272-1742 Fax: 519-273-3298
Email: w.ham@bellnet.ca

Boundary Garlic
www.garlicfarm.ca
Box 273
Midway, BC V0H 1M0
Phone: 250-449-2152
E-mail: sonia@garlicfarm.ca

Dominion Seed House
www.dominion-seed-house.com
Box 2500
Georgetown, ON L7G 5L6
Phone: 905-873-3037 Fax: 1-800-282-5746

Evergreen Seeds
(Oriental Vegetable Seeds)
www.store.yahoo.com/evergreenseeds/index.html
Box 17538
Anaheim, CA 92817 USA
Phone/Fax: 714-637-5769

Fred Fuller Seeds Ltd.
(Sales Agent for Co-Op Uniforce, Quebec)
Fred Fuller
19075 Dufferin St.
Newmarket, ON L3Y 4V9
Phone: 905-775-9696 Fax: 905-775-4783
E-mail: fuller.seeds@on.aibn.com

Harris-Moran
www.harrismoran.com
Contact:
John Molyet, Fresh Market
Senior Sales Representative
Eastern Canada, Northwestern/Midwestern USA
Phone/Fax: 419-992-4390
E-mail: j.molyet@harrismoran.com

Heirloom Acres Seeds
www.heirloomacres.net
Box 194
2529 County Road 338
New Bloomfield, MO, 65063 USA
Phone: 573-491-3001 Fax: 573-491-3002

Johnny's Selected Seeds
www.johnnyseeds.com
955 Benton Avenue
Winslow, Maine 04901-2601 USA
Phone: 207-861-3999 or 1-800-738-6314 (within US only)
Fax: 207-861-8377
E-mail: service@johnnyseeds.com

Ontario Seed (OSC)
www.oscseeds.com
Box 7
Waterloo, ON N2J 3Z6
Phone: 519-886-0557 Fax: 519-886-0605
E-mail: seeds@oscseeds.com

Ornamental Edibles
www.ornamentaledibles.com
5723 Trowbridge Way
San Jose, CA 95138 USA
Phone: 408-528-7333 Fax: 408-532-1499
E-mail: seeds@ornamentaledibles.com

Redwood City Seed Co.
www.ecoseeds.com
Craig & Sue Dremann
Box 361
Redwood City, CA 94064 USA
Phone: 650-325-7333 Fax: 650-325-4056

Reed's Seeds
3334 N.Y.S. Rt. 215
Courtland, NY 13045-9433 USA
Phone: 607-753-9095 Fax: 607-753-9511

Richter's (Herbs)
www.richters.com
357 Highway 47
Goodwood, ON L0C 1A0
Phone: 905-640-6677 Fax: 905-640-6641
E-mail: orderdesk@richters.com

Rispens Seeds Inc.
www.rispensseeds.com
1357 Dutch American Way, P.O. Box 310
Beecher, IL 60401 US
Phone: 708-946-6560 (Canada) or 1-888-874-0241 (U.S. only)
Fax: 708-946-6115

Rupp Seeds
www.ruppseeds.com
George Wonnacott
135 Lancefield Place
Chatham, ON N7L 2M5
Phone: 519-354-0206 Fax: 519-354-0287
E-mail: gdwonnacott@primus.ca

Sakata Seed Inc.
www.sakata.com
Dennis Thome
1365 Southbates St.
Birmingham, Michigan 48009 US
Phone: 248-709-5684
E-mail: dthome@sakata.com

Seedway/Bejo
(Distributors of Bejo Varieties)
www.seedway.com
99 Industrial Rd.
Elizabethtown, PA 17022 USA
Phone: 1-800-952-7333 Fax: 1-800-645-2574

Siegers Seed Company
Ernie Szucs
Cell: 814-460-4102
Phone: 519-586-2110 Fax: 519-586-2555
E-mail: ernie_szucs@siegers.com

Stokes Seeds
www.stokeseeds.com
Paul Banks
Box 10
Thorold, ON L2V 5E9
Phone: 1-800-263-7233

Jim Robinson
Box 144
Rockton, ON L0R 1X0
Phone: 905-715-8595

Syngenta Seeds
77 Southridge
Springgrove, PA 17362 US
Bill Rankin, Processing
Phone: 717-225-5557 Fax: 717-739-1032
E-mail: b.rankin@syngenta.com

Terralink Horticulture Inc.
www.terralink-horticulture.com/index.htm
464 Riverside Rd.
Abbotsford, BC V2S 7M1
Phone: 1-800-661-4559 or 604-864-9044
Fax: 604-864-8418

Tomato Growers' Supply Company
www.tomatogrowers.com
P.O. 60015
Fort Myers, FL, 33906 USA
Phone: 1-239-768-1119

Tomato Solutions
Jim Dick
R. R. # 4, 23264 Mull Rd.
Chatham, ON N7M 5J4
Phone: 519-354-3039 or 1-877-833-7358
Fax: 519-354-2058
E-mail: jimdick@netrover.com

Totally Tomatoes
www.totallytomato.com
334 West Stroud St.
Randolph, WI 53956-1274 US
Phone: 1-800-345-5977 Fax: 1-888-477-7333
E-mail: info@totallytomato.com

Vesey's Seeds
www.veseys.com
Box 9000
Charlottetown, PE, C1A 8K6
Phone: 1-800-363-7333 Fax: 1-800-686-0329

William Dam Seeds
www.damseeds.com
Box 279, Highway # 8
Dundas, ON L9H 5E1
Phone: 905-628-6641 Fax: 905-627-1729
E-mail: info@damseeds.com

Appendix E.
Crop Insurance

The Canada-Ontario Crop Insurance Program is publicly funded by the Government of Canada and the Province of Ontario and delivered by Agricorp. The federal and provincial governments contribute up to 60 percent of the premium cost and 100 percent of the administrative costs. Both these contributions enable an Ontario grower to purchase insurance coverage at a substantially reduced cost.

The grower's payment is considered an operating expense for income tax purposes. As long as recommended control practices are followed, Production Insurance offers protection against a broad range of production hazards, including excessive rain, hail, excessive drought, freeze, frost, excessive wind, insect infestation and plant disease.

For further information, please call Agricorp at 1-888-247-4999.

Agricorp
1 Stone Rd. W.
Box 3660, Stn. Central
Guelph, ON N1H 8M4
Tel: 1-888-247-4999
Fax: 519-826-4118
E-mail: contact@agricorp.com
www.agricorp.com

Ontario Crops Covered by a Crop Insurance Plan

Fruit Crops		
apples and apple trees	cherries, sweet and sour	grapes and grape vines
peaches/nectarines	pears	plums
strawberries		
Vegetable Crops – Average Farm Yield or Total Production		
asparagus	banana peppers	bell peppers
broccoli	green beans and wax beans (processing)	butternut squash (processing)
cabbages	carrots (fresh)	carrots (processing)
cauliflower	celery	cucumbers (processing)
lettuce	lima beans (processing)	parsnips
peas (processing)	potatoes (fresh)	potatoes (processing)
red beets (processing)	rutabagas	seed onions
set onions	spanish onions	sweet corn (fresh)
sweet corn (processing)	tomatoes (fresh)	tomatoes (processing)
Fresh Market Vegetables – Acreage Loss		
Root Vegetables (red beets, carrots, celeriac, French shallots, green onions, leeks, onions, parsnips, radishes, rutabagas, turnips)		
Leafy Vegetables (brussels sprouts, broccoli, cauliflower, broccoflower, celery, Chinese cabbages, green cabbage, lettuce, mesclun, spinach)		
Fruit Vegetables (cucumbers, eggplant, gherkins, melons, peppers, pumpkins, squash, tomatoes, zucchinis)		
Other Vegetables (broad beans, fresh market beans, sweet corn, green beans)		
General Crops		
canola	coloured beans (black, cranberry, Kidney, Japanese/other)	corn (grain and silage)
forage	hemp, industrial	honey
mustard	new forage seeding	peanuts
popping corn	soybeans (tofu, natto and organic options available)	spring grain
seed corn	spring wheat	sugarbeets
sunflower	white beans	winter spelt, organic
winter wheat, hard red	winter wheat, organic	winter wheat, soft red
winter wheat, soft white		
Tobacco		
black	burley	flue-cured

Appendix F.
Other Contacts

AGRICULTURE & AGRI-FOOD CANADA RESEARCH CENTRES

Eastern Cereals and Oilseeds Research Centre
960 Carling Ave.
Ottawa, K1A 0C6
Tel: 613-759-1952
http://res2.agr.ca/ecorc/index_e.htm

Greenhouse and Processing Crops Centre
2585 County Road 20
Harrow, N0R 1G0
Tel: 519-738-2251
http://res2.agr.ca/harrow/

Southern Crop Protection and Food Research Centre
http://res2.agr.ca/london/pmrc/index_e.htm

1391 Sandford St.
London N5V 4T3
Tel: 519-457-1470

Vineland Research Farm
4902 Victoria Ave. N.
Vineland L0R 2E0
Tel: 905-562-4113

Delhi Research Farm
Box 186 Schafer Rd.
Delhi N4B 2W9
Tel: 519-582-1950

CANADIAN FOOD INSPECTION AGENCY REGIONAL OFFICES (PLANT PROTECTION)

www.inspection.gc.ca/english/toce.shtml

Belleville
345 College St. E.
Belleville, K8N 5S7
Tel: 613-969-3333

Brantford
625 Park Road North, Suite 6
Brantford, N3T 5P9
Tel: 519-753-3478

Hamilton
709 Main St. W., Ste. 101
Hamilton, L8S 1A2
Tel: 905-572-2201

London
19-100 Commissioners Road East
London, N5Z 4R3
Tel: 519-691-1300

St. Catharines
395 Ontario Stree, Box 19
St. Catharines, L2N 7N6
Tel: 905-937-8232

Ottawa District
38 Auriga Dr., Unit 8
Ottawa K2E 8A5
Tel: 613-274-7374, ext. 221

Toronto
1124 Finch Ave. W., Unit 2
Downsview, M3J 2E2
Tel: 416-665-5055
Fax: 416-665-5069

UNIVERSITY OF GUELPH

Main Campus
Guelph, N1G 2W1
Tel: 519-824-4120
www.uoguelph.ca

Alfred Campus
Alfred, K0B 1A0
Tel: 613-679-2218
Fax: 613-679-2423
www.alfredc.uoguelph.ca

Kemptville Campus
Kemptville, K0G 1J0
Tel: 613-258-8336
Fax: 613-258-8384
www.kemptvillec.uoguelph.ca

Ridgetown Campus
Ridgetown, N0P 2C0
Tel: 519-674-1500
www.ridgetownc.on.ca

Department of Plant Agriculture
www.plant.uoguelph.ca

Department of Plant Agriculture, Guelph
50 Stone Rd. W.
Guelph, ON
N1G 2WI
Tel: 519-824-4120, ext. 56083
Fax: 519-763-8933

Department of Plant Agriculture, Simcoe
1283 Blueline Road, Box 587
Simcoe, N3Y 4N5
Tel: 519-426-7127
Fax: 519-426-1225

Department of Plant Agriculture, Vineland
Box 7000, 4890 Victoria Ave. N.
Vineland Station, L0R 2E0
Tel: 905-562-4141
Fax: 905-562-3413
Lab Services Division
www.uoguelph.ca/labserv/

Pesticide and Trace Contaminants
P.O. Box 3650, 95 Stone Rd. W.
Guelph, N1H 8J7
Tel: 519-767-6299

Pest Diagnostic Clinic
Tel: 519-767-6256

Appendix G. Diagnostic Services

Samples for disease diagnosis, insect or weed identification, nematode counts and *Verticillium* testing can be sent to:

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Rd. W.
Guelph Ontario, N1H 8J7

Tel: 519-767-6256
Fax: 519-767-6240
E-mail: pdc@lsd.uoguelph.ca

Payment must accompany samples at the time of submission. Submission forms are available at www.uoguelph.ca/pdc.

Fee Schedule

To obtain information on the fee schedule, visit www.uoguelph.ca/pdc or phone the Pest Diagnostic Clinic.

How to Sample for Nematodes

Soil

When to Sample

Soil and root samples can be taken at any time of the year that the soil is not frozen. In Ontario, nematode soil population levels are generally at their highest in May and June and again in September and October.

How to Sample Soil

Use a soil sampling tube, trowel or narrow-bladed shovel to take samples. Sample soil to a depth of 20–25 cm (8–10 in.). If the soil is bare, remove the top 2 cm (1 in.) prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of $^1/_2$-1 L (1 pint–1 quart) from this. No one sample should represent more than 2.5 ha (6.25 ac). Mix subsamples in a clean pail or plastic bag.

Sampling Pattern

If living crop plants are present in the sample area, take samples within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of Subsamples

Based on the total area sampled:
500 m^2 (5,400 ft^2)10 subsamples
500 m^2-0.5 ha (5,400 ft^2-1.25 ac)25 subsamples
0.5 ha–2.5 ha (1.25–6.25 ac)50 subsamples

Roots

From small plants, sample the entire root system plus adhering soil. For large plants, 10–20 g ($^1/_2$-1 oz.) dig fresh weight from the feeder root zone and submit.

Problem Areas

Take soil and root samples from the margins of the problem area where the plants are still living. If possible, also take samples from healthy areas in the same field. If possible, take both soil and root samples from problem and healthy areas in the same field.

Sample Handling

Soil Samples

Place in plastic bags as soon as possible after collecting.

Root Samples

Place in plastic bags and cover with moist soil from the sample area.

Storage

Store samples at 5°C–10°C (40°C–50°F) and do not expose them to direct sunlight or extreme heat or cold (freezing). **Only living nematodes can be counted. Accurate counts depend on proper handling of samples.**

Submitting Plant for Disease Diagnosis or Identification

Sample Submission Forms

Forms can be obtained from your local Ontario Ministry of Agriculture, Food and Rural Affairs office. Carefully fill in all of the categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past 3 years and this year's pesticide use records.

Choose a complete, representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system, or several plants showing a range of symptoms. If symptoms are general, collect the sample from an area where they are of intermediate severity. **Completely dead material is usually inadequate for diagnosis.**

With plant specimens submitted for identification, include at least a 20–25-cm sample of the top portion of the stem with lateral buds, leaves, flowers or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid drying out and contamination of the leaves by soil. Do **NOT** add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping. Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery

Deliver to the Pest Diagnostic Clinic as soon as possible by first class mail or by courier at the beginning of the week.

Submitting Insect Specimens for Identification

Collecting Samples

Place dead, hard-bodied insects in vials or boxes and cushion with tissues or cotton. Place soft-bodied insects and caterpillars in vials containing alcohol. Do not use water, as this results in rot. Do not tape insects to paper or send them loose in an envelope.

Place live insects in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.

UNIVERSITY of GUELPH LABORATORY SERVICES

95 Stone Road West
Guelph, ON N1H 8J7
Tel: (519) 767-6256
Fax: (519) 767-6240
Web: www.uoguelph.ca/pdc

Pest Diagnostic Clinic

SAMPLE SUBMISSION FORM

LABORATORY USE ONLY: **LS Form: SubP01/04/03**

Rec'd: By:____________ **Date Received:** ____________

Delivered By: ☐ **Mail** ☐ **Courier** ☐ **In-Person**

LS Sample No: ____________ **to** ____________

Payment Rec'd: $____________ **Receipt #:**____________

Submitted By:

Business Name (if applicable):

Street:

City: Prov: Postal Code:

Tel: ( ) - Fax: ( ) -

Email:

Owner (if different from submitter):

Business Name (if applicable):

Street:

City: Prov: Postal Code:

Tel: ( ) - Fax: ( ) -

Email:

Unless otherwise indicated, report and invoice will be sent to submitter

Report to: ☐ Submitter ☐ Owner

Required Report Format: ☐ Fax ☐ E-Mail ☐ Mail

Invoice to: ☐ Submitter ☐ Owner Quotation #: ________

Purchase Order / U of G G/L code:____________

Services Required: ☐ Nematode Count ☐ Nematode Count from Roots ☐ SCN Cyst & Egg Count ☐ Verticillium Count ☐ Plant Disease Diagnosis ☐ Insect Identification ☐ Plant Identification ☐ Triazine Resistance Test

Plant or Host Affected:

Cultivar/Variety:

Grower/Field sample #:

Location of Plant (i.e. greenhouse, field, orchard, garden, etc.):

Size of Planting:

% of Plants Affected:

Symptoms First Appeared in Past: ☐ Days ☐ Weeks ☐ Months ☐ Years

Degree of Injury: ☐ Severe ☐ Moderate ☐ Light

Cropping History:

Future Crop:

Describe the problem in detail (i.e. symptoms, plant parts affected, distribution of symptoms):

Were chemicals applied? Please specify type of product(s) used and date(s) of application:

Additional comments and specific requests:

Additional Sheet(s) Attached: ☐

Appendix H.
The Metric System

Metric Units

Linear Measures (length)		
10 millimetres (mm)	=	1 centimetre (cm)
100 centimetres (cm)	=	1 metre (m)
1,000 metres	=	1 kilometre (km)

Square Measures (area)		
100 m x 100 m = 10,000 m^2	=	1 hectare (ha)
100 ha	=	1 square kilometre (km^2)

Cubic Measures (volume)		
Dry Measure		
1,000 cubic millimetres (mm^3)	=	1 cubic centimetre (cm^3)
1,000,000 cm^3	=	1 cubic metre (m^3)
Liquid Measure		
1,000 millilitres (mL)	=	1 litre (L)
100 L	=	1 hectolitre (hL)

Weight-Volume Equivalents (for water)		
(1.00 kg) 1,000 grams	=	1 litre (1.00 L)
(0.50 kg) 500 g	=	500 mL (0.50 L)
(0.10 kg) 100 g	=	100 mL (0.10 L)
(0.01 kg) 10 g	=	10 mL (0.01 L)
(0.001 kg) 1 g	=	1 mL (0.001 L)

Weight Measures		
1,000 milligrams (mg)	=	1 gram (g)
1,000 g	=	1 kilogram (kg)
1,000 kg	=	1 tonne (t)
1 mg/kg	=	1 part per million (ppm)

Dry–Liquid Equivalents		
1 cm^3	=	1 mL
1 m^3	=	1,000 L

Calculating Parts per Million (ppm)		
1 ppm	=	1 g active ingredient per 1,000 L water

Handy Metric Conversion Factor		
litres per hectare x 0.4	=	litres per acre
kilograms per hectare x 0.4	=	kilograms per acre

Application Rate Conversions

Metric to Imperial (Approximate)		
litres per hectare x 0.09	=	gallons per acre
litres per hectare x 0.36	=	quarts per acre
litres per hectare x 0.71	=	pints per acre
millilitres per hectare x 0.015	=	fluid ounces per acre
grams per hectare x 0.015	=	ounces per acre
kilograms per hectare x 0.89	=	pounds per acre
tonnes per hectare x 0.45	=	tons per acre

Imperial to Metric (Approximate)		
gallons per acre x 11.23	=	litres per hectare (L/ha)
quarts per acre x 2.8	=	litres per hectare (L/ha)
pints per acre x 1.4	=	litres per hectare (L/ha)
fluid ounces per acre x 70	=	millilitres per hectare (mL/ha)
tons per acre x 2.24	=	tonnes per hectare (t/ha)
pounds per acre x 1.12	=	kilograms per hectare (kg/ha)
ounces per acre x 70	=	grams per hectare (g/ha)

Liquid Equivalents

Litres/Hectare		*Approximate Gallons/Acre*
50	=	5
100	=	10
150	=	15
200	=	20
250	=	25
300	=	30

Dry Weight Equivalents

Grams or Kilograms / Hectare		*Ounces or Pounds /Acre*
100 grams	=	$1\frac{1}{2}$ ounces
200 grams	=	3 ounces
300 grams	=	$4\frac{1}{4}$ ounces
500 grams	=	7 ounces
700 grams	=	10 ounces
1.10 kilograms	=	1 pound
1.50 kilograms	=	$1\frac{1}{4}$ pounds
2.00 kilograms	=	$1\frac{3}{4}$ pounds
2.50 kilograms	=	$2\frac{1}{4}$ pounds
3.25 kilograms	=	3 pounds
4.00 kilograms	=	$3\frac{1}{2}$ pounds
5.00 kilograms	=	$4\frac{1}{2}$ pounds
6.00 kilograms	=	$5\frac{1}{4}$ pounds
7.50 kilograms	=	$6\frac{3}{4}$ pounds
9.00 kilograms	=	8 pounds
11.00 kilograms	=	10 pounds
13.00 kilograms	=	$11\frac{1}{2}$ pounds
15.0 kilograms	=	$13\frac{1}{2}$ pounds

Metric Conversions		
5 mL	=	1 tsp
15 mL	=	1 tbsp
28.5 mL	=	1 fl. oz

Conversion Tables — Metric to Imperial

Length

1 millimetre (mm) = 0.04 inch
1 centimetre (cm) = 0.40 inch
1 metre (m) = 39.40 inches
1 metre (m) = 3.28 feet
1 metre (m) = 1.09 yards
1 kilometre (km) = 0.62 mile

Area

1 square centimetre (cm^2) = 0.16 square inch
1 square metre (m^2) = 10.77 square feet
1 square metre (m$^{2)}$ = 1.20 square yards
1 square kilometre (km^2) = 0.39 square mile
1 hectare (ha) = 107,636 square feet
1 hectare (ha) = 2.5 acres

Volume (dry)

1 cubic centimetre (cm^3) = 0.061 cubic inch
1 cubic metre (m^3) = 1.31 cubic yards
1 cubic metre (m^3) = 35.31 cubic feet
1,000 cubic metres (m^3) = 0.81 acre-foot
1 hectolitre (hL) = 2.8 bushels

Volume (liquid)

1 millilitre (mL) = 0.035 fluid ounce
1 litre (L) = 1.76 pints
1 litre (L) = 0.88 quart
1 litre (L) = 0.22 gallon (Imp.)
1 litre (L) = 0.26 gallon (U.S.)

Weight

1 gram (g) = 0.035 ounce
1 kilogram (kg) = 2.21 pounds
1 tonne (t) = 1.10 short tons
1 tonne (t) = 2,205 pounds

Pressure

1 kilopascal (kPa) = 0.15 pounds/in^2

Speed

1 metre per second = 3.28 feet per second
1 metre per second = 2.24 miles per hour
1 kilometre per hour = 0.62 mile per hour

Temperature

°F = (°C X $^9/_5$) + 32

Conversion Tables — Imperial to Metric

Length

1 inch = 2.54 cm
1 foot = 0.30 m
1 yard = 0.91 m
1 mile = 1.61 km

Area

1 square foot = 0.09 m^2
1 square yard = 0.84 m^2
1 acre = 0.40 ha

Volume (dry)

1 cubic yard = 0.76 m^3
1 bushel = 36.37 L

Volume (liquid)

1 fluid ounce (Imp.) = 28.41 mL
1 pint (Imp.) = 0.57 L
1 gallon (Imp.) = 4.55 L
1 gallon (U.S.) = 3.79 L

Weight

1 ounce = 28.35 g
1 pound = 453.6 g
1 ton = 0.91 tonne

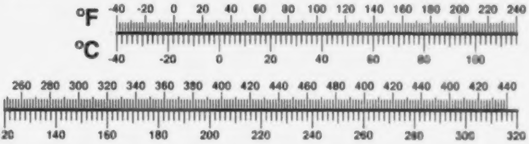
Pressure

1 pound per square inch = 6.90 kPa

Temperature

°C = (°F – 32) x $^5/_9$

TEMPERATURE



For exact values the formula is:
Fahrenheit to Celsius: subtract 32 from number of °F, then multiply by $^5/_9$.
Celsius to Fahrenheit multiply °C by $^9/_5$ then add 32.

Abbreviations

% = per cent (by weight)
ai = active ingredient
AP = agricultural powder
cm = centimetre
cm^2 = square centimetre
DG = dispersible granular
DP = dispersible powder
E = emulsifiable
e. g. = for example
EC = emulsifiable concentrate
F = flowable
g = gram
Gr = granules, granular
ha = hectare
kg = kilogram
km = kilometre
km/h = kilometres per hour
kPa = kilopascal
L = litre
m = metre
m^2 = square metre
mL = millilitre
mm = millimetre
m/s = metres per second
SC = sprayable concentrate
SP = soluble powder
t = tonne
W = wettable (powder)
WDG = water dispersible granular
WP = wettable powder

Emergency and First Aid Procedures for Pesticide Poisoning

For a major spill, a theft or a fire involving a pesticide call the Ministry of the Environment at **1-800-268-6060.**

For pesticide poisonings and pesticide injuries call the **Poison Information Centre:**

Toronto	1-800-268-9017
Hearing Assistance (TTY)	1-877-750-2233

PREVENT ACCIDENTS

- **Read the label.** Follow all the precautions the label recommends. Read the First Aid section of the label BEFORE you begin to handle any pesticide.
- **Make sure that someone knows** what pesticides you are working with and where you are.
- **Keep a file of labels and product Material Safety Data Sheets (MSDS) for the pesticides you use.** Make sure everyone knows where to find this in case of an emergency.
- **Post emergency numbers near all telephones.**
- **Keep clean water, paper towels, extra gloves and clean coveralls close by** in case you spill pesticide on yourself.

If someone has been working with pesticides and you see any possible symptoms of pesticide poisoning or injury, take emergency action immediately.

IF AN ACCIDENT OR POISONING HAPPENS

- Protect yourself from injury first.
- Stop the exposure to the pesticide. Move the victim away from the contaminated area.
- Check the four basic facts — identify the pesticide, the quantity, the route of entry and time of exposure.
- Call an ambulance or the Poison Information Centre. Start first aid. This is not a substitute for professional medical help.
- **Provide the label, MSDS sheet or container to emergency personnel** at the scene — or take it with you to the hospital. Do not transport pesticide containers in the passenger compartment of the vehicle.

FIRST AID

If a pesticide comes in contact with skin:

- remove all contaminated clothing; wash skin thoroughly with lots of soap and warm water
- dry skin well and cover with clean clothing or other clean material.

If pesticide comes in contact with eyes:

- hold eyelids open; wash the eyes with clean running water for 15 minutes or more.

If pesticide was inhaled:

- move the victim to fresh air and loosen tight clothing
- give artificial respiration if the victim is not breathing.

Do not breathe in the exhaled air from the victim — you could also be poisoned.

If a pesticide was swallowed:

- **call the Poison Information Centre IMMEDIATELY.**

Emergency numbers are listed at the front of each Bell telephone directory.

For information, or to obtain copies of this or any other ministry publication please:
call 1-888-466-2372 from within Ontario, 519-826-3700 from outside the province or OMAFRA's TTY line at 519-826-7402 for the hearing impaired, e-mail your request to *products.omafra@ontario.ca*, or visit OMAFRA's website at *ontario.ca/omafra*.

A complete list of all OMAFRA products and services, and order forms, are available on the website. Orders can be faxed to 519-826-3633 or mailed to ServiceOntario, 1 Stone Road West, Guelph, Ontario N1G 4Y2.

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